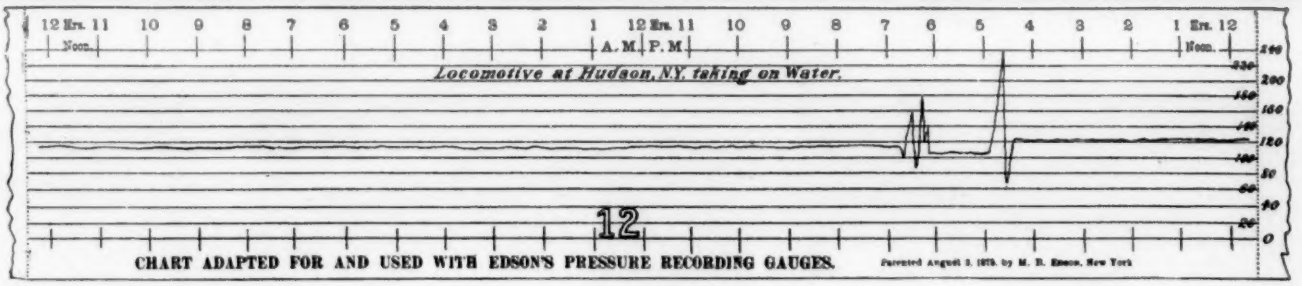

12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
Noon. A.M. P.M. Noon.
Locomotive at Hudson, N.Y. taking on Water.
12
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.
Patented August 3, 1875. by M. B. Edson. New York

PLATE No. 6.

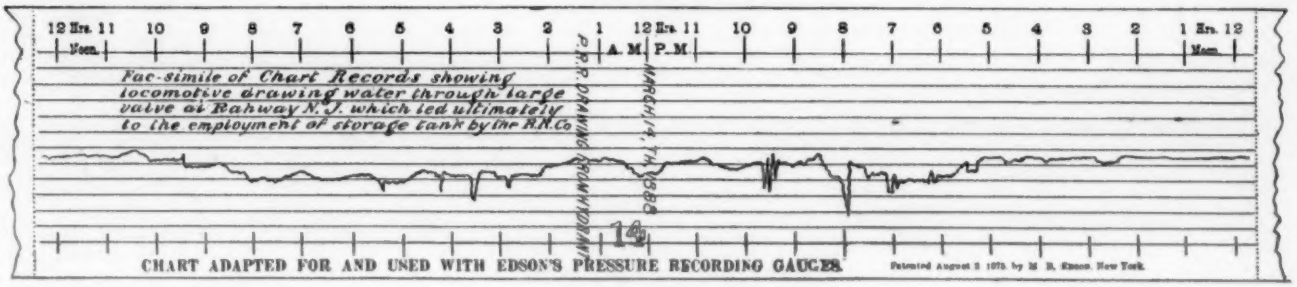

12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
Noon. A.M. P.M. Noon.
Fac-simile of Chart Records showing locomotive drawing water through large valve at Rahway N.J. which led ultimately to the employment of storage tank by the P.R.R.Co
P.R.R. DRAWING FROM HUDSON MARCH 14, TH 1883
14
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.
Patented August 3 1875. by M. B. Edson. New York.

PLATE No. 7.

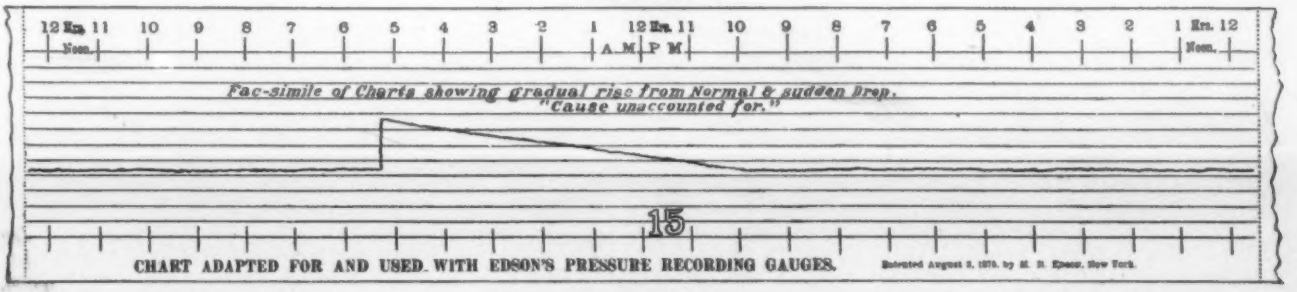

12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
Noon. A.M. P.M. Noon.
Fac-simile of Charts showing gradual rise from Normal & sudden Drop.
"Cause unaccounted for."
15
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.
Patented August 3, 1875. by M. B. Edson. New York.

PLATE No. 8.

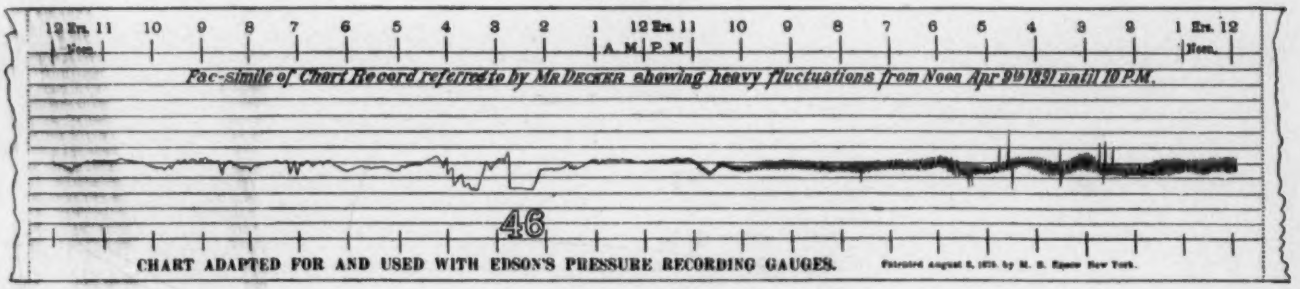
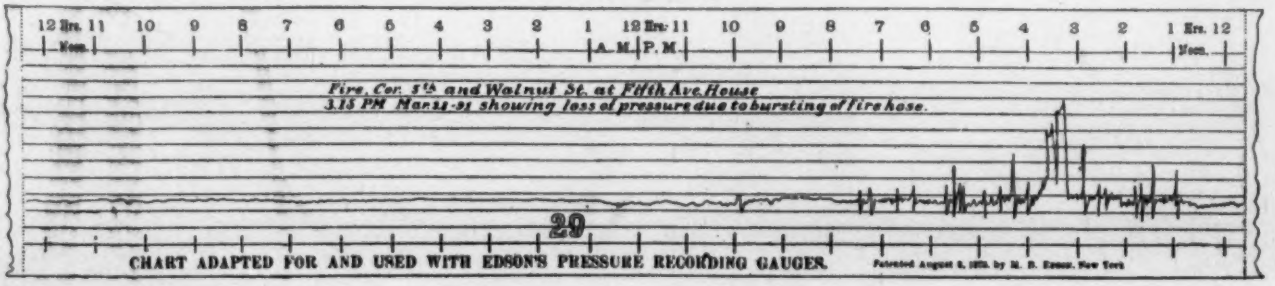

12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
Noon. A.M. P.M. Noon.
Fac-simile of Chart Record referred to by Mr DECKER showing heavy fluctuations from Noon Apr 9th 1891 until 10 P.M.
46
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.
Patented August 3, 1875. by M. B. Edson New York.

PLATE No. 9.


12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
Noon. A.M. P.M. Noon.
Fire, Cor. 5th and Walnut St. at Fifth Ave. House
3.15 PM March 31-91 showing loss of pressure due to bursting of fire hose.
29
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.
Patented August 3, 1875. by M. B. Edson. New York

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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[*Being the report of the Committee on Science and the Arts, adopted November 1, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 30, 1893.

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The recording apparatus is mounted on the top of the base *A*, and the movement of the diaphragm *C* is transmitted through the arms H^2 and H^3, on the rock shaft *H*, by means

PLATE No. 1.

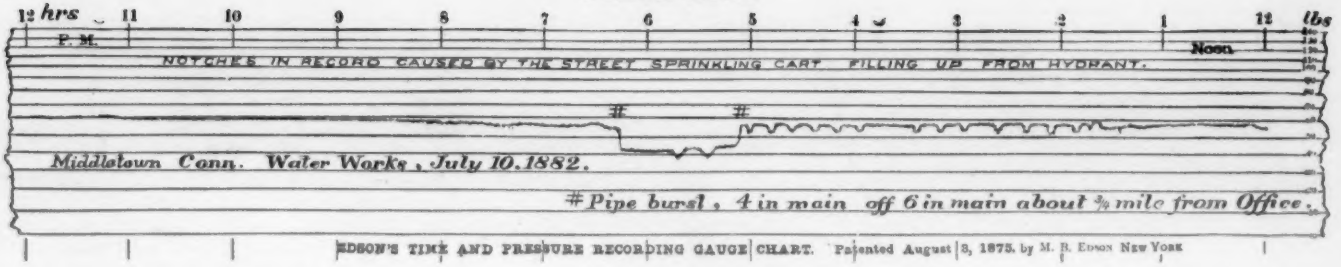
12 hrs
P. M.
Noon
lbs
NOTCHES IN RECORD CAUSED BY THE STREET SPRINKLING CART FILLING UP FROM HYDRANT.
Middletown Conn. Water Works, July 10. 1882.
#Pipe burst, 4 in main off 6 in main about ¾ mile from Office.
EDSON'S TIME AND PRESSURE RECORDING GAUGE CHART. Patented August 3, 1875. by M. B. Edson New York

PLATE No. 2.

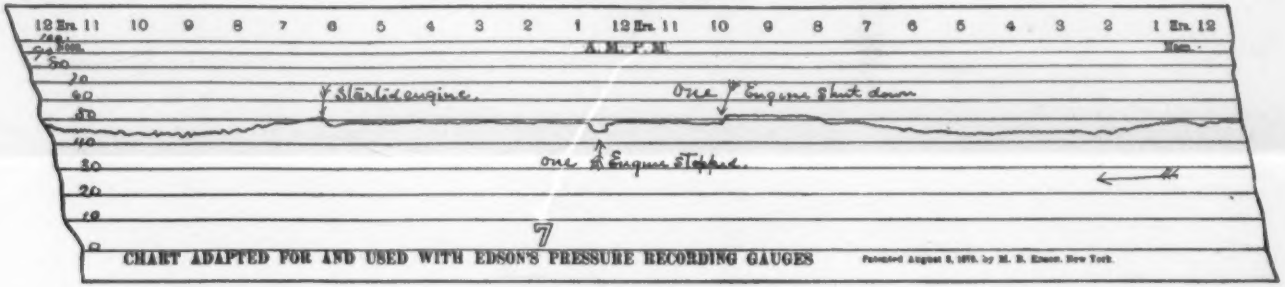
12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
A. M. P. M.
Noon.
Starting engine.
One Engine Shut down
One Engine Stopped.
7
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES

PLATE No. 3.

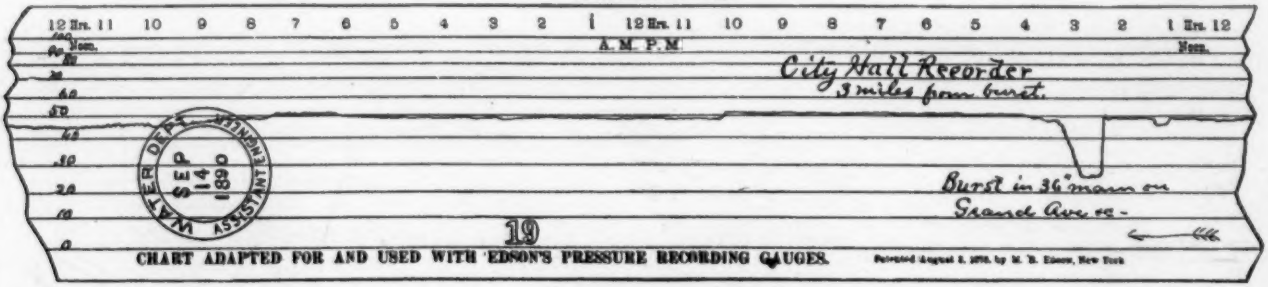
12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
A. M. P. M.
Noon.
City Hall Recorder
3 miles from burst.
Burst in 36" main on
Grand Ave ue -
WATER DEPARTMENT SEP 14 1880 ASSYRIA
19
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.

PLATE No. 4.

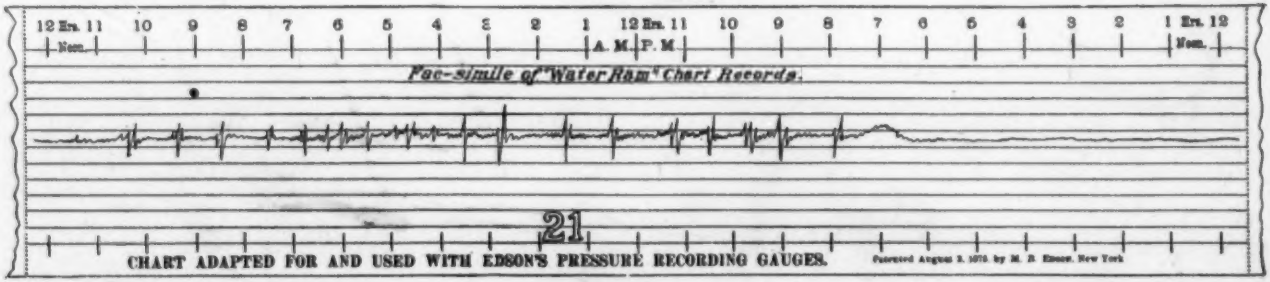
12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 12 Hrs. 11 10 9 8 7 6 5 4 3 2 1 Hrs. 12
Noon
A. M. P. M
Noon
Fac-simile of "Water Ram" Chart Records.
21
CHART ADAPTED FOR AND USED WITH EDSON'S PRESSURE RECORDING GAUGES.

PLATE No. 5.

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The instrument (*Fig. 1*) consists of a metal base *A*, enclosing beneath it a tempered diaphragm *C*, so arranged that when the fluid enters the space *D*, between the spring and the cap *E*, forming the chamber, the spring is deflected upwards.

The recording apparatus is mounted on the top of the base *A*, and the movement of the diaphragm *C* is transmitted through the arms H^2 and H^3, on the rock shaft *H*, by means

of the connecting bar *G*, to the vertical moving pencil carrier in front, describing about six times the original travel of the diaphragm. Simultaneously therewith, the same rock shaft *H* moves the hand M^2 before the dial *M*.

A special clock mechanism revolves the receiving reel K^2, contributing the element of time to the chart drawn from the reservoir reel *K*, on the right beneath the recording pencil.

Ordinarily this reservoir reel *K* contains a supply of charts for thirty days. A glass dome surmounting the whole allows inspection and excludes dust, moisture, etc.

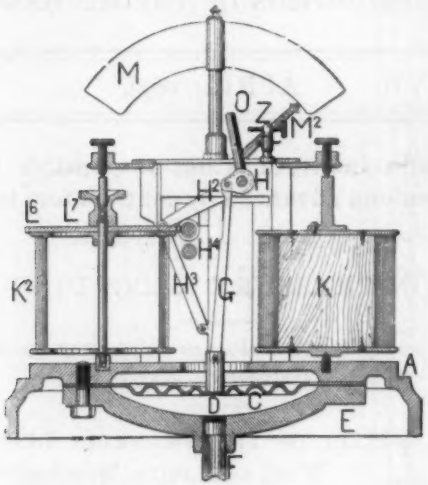


FIG. 1—Sectional view.

The supplemental adjustable arm *O*, upon the rock shaft *H*, acts as a circuit-closer for an electro-magnetic alarm, and operates a mechanical alarm usually provided with each instrument.

This style of recorder has been found successful in recording pressures from two pounds per square inch, for blast furnaces, to 1,200 pounds per square inch, used in pumping oil.

For recording temperatures of drying rooms, etc., a supplemental diaphragm is employed to increase the travel, owing to the low coëfficient of expansion of the fluids used.

The instrument has been gradually developed through more than twenty years, the first of a series of patents, covering the invention, bearing date of May 5, 1868 (No. 77,584). The present style of gauge was adopted and

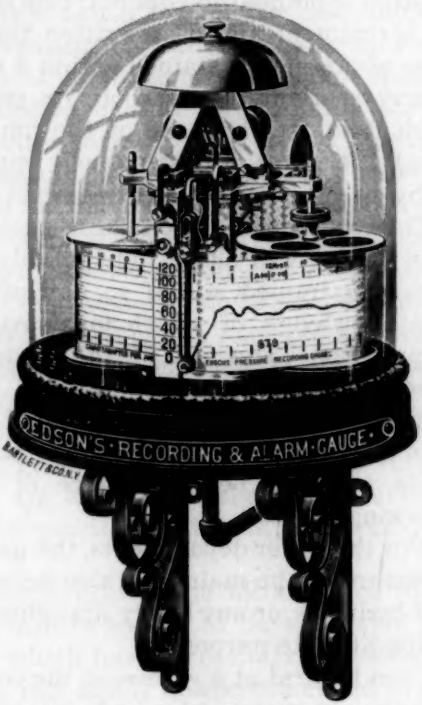


FIG. 2.

patented August 16, 1870 (No. 106,345). The latest patent bears date of December 23, 1890 (No. 443,360), and shows the most improved form of the instrument. (*Fig. 2.*)*

* It will be observed that the sectional view of the Edson gauge, shown in *Fig. 1*, exhibits some differences in details of construction as compared with the most recent form of the apparatus shown in *Fig. 2*. This may be explained on the ground that this report is, in a measure, historical in character.

The new style of instrument, above referred to, has no hand or dial, and in its construction the employment of mechanism H, H^2, H^3 and H^4 is avoided, as also the hand and dial and corresponding rack and pinion, reliance being placed upon the small vertical scale standing immediately over the chart, which is ruled precisely as the chart is, and corresponds precisely with

No other recording gauge is similar in construction, as an inspection of the appended list of letters-patent will show. This list substantially covers the ground of recording gauges, and the patents embraced therein were studied by the sub-committee appointed to conduct this investigation.

The Edson instrument affords a written tracing or log of every degree of pressure sustained within a steam boiler, tank, pipe, or any reservoir, of water, oil, air, steam or other liquid, to which it is attached, and of the time when such pressure existed. It gives, if continuously applied, a complete biography of a boiler and a correct exhibit of all the work done. The recorder is a good check on night guards, and if regularly kept, will show indisputably whether a boiler has been overstrained, and, if so, how often this has happened, the knowledge of which may save many lives and valuable property. The fact of the existence of this continuous and easily interpreted chart will undoubtedly tend to make firemen both careful and proud of their record, while giving to their employers evidence of facts not otherwise obtainable and the best assurance of careful and economical working.

When used in the water departments, the gauge not only verifies the pressure on the mains, but also detects leaks and the opening of hydrants, or any heavy draughts of water for legitimate or illegitimate purposes.

The record can be read at a glance, as the co-ordinates of time and pressure are rectangular and not circular as in

---

the travel of the spring. Its indications are more accurate than those at the end of the pointer-head on the segmental arc in the old style of recorder, for the reason that some lost motion is possible in the mechanism required to change the direction of, and multiply the motion derived directly from, the diaphragm spring. The office of the Edson Recorder is not that of an *indicating* gauge, but that of a *recording* gauge. Its extreme sensitiveness, resulting from large original travel, renders its more finely graduated dial even more reliable than a large dial with a pointer-hand moving with an enormous multiplication of the original spring travel, as in other styles of gauges. In order, therefore, to simplify the instrument, and remove wearing surfaces and lost motion, as well as to reduce the first cost, the new style of instrument (*Fig. 2*), with the valuable additional feature of the electric circuit-closer, and without hand and dial, has been given the preference over the older style with hand and dial. W. H. W.

most of the other recording gauges. The latter system does not give as clear a picture of the variations of pressure and appertaining parts of time as the former.

The Edson pressure recording gauge has been in service for many years, and a few of the testimonials submitted to the investigating committee clearly show the durability and practical value of the instruments. These testimonials without exception exhibit the fact that the gauges have done their work perfectly and to the great satisfaction of their owners, and that continuously, for periods, in some instances, up to twelve years.

Among others, the National Transit Company (oil pipe-line) has had in service, during the last six years, about 140 of the Edson instruments, one-half of which are recording from 0 to 800 and as high as 1,500 pounds per square inch. With but one exception, none of these have ever been returned for repairs. The Illinois Steel Company has in constant operation forty-five gauges. The list of the patrons of the Edson pressure recording gauge is very long, and the best names are among them, and their evidence as to the efficiency and practical value is, uniformly, highly favorable.

It can, therefore, safely be affirmed that the Edson gauge has proved itself in service to be a reliable and well-made instrument, which has successfully stood the severe test of time, and it can safely be recommended to every owner of a steam boiler in the interests of safety and economy.

The recording gauge shows its superior qualities not only in connection with the steam boiler, but also in all cases where fluids are kept under pressure. It is, therefore, very desirable to use in connection with gas and water-pipe systems, oil-pipe lines and tanks, blast furnaces, etc.

Its extremely close accuracy makes this gauge very valuable in the various industries where uniformity of pressure is indispensable for the best production and highest efficiency of a manufacturing or other plant.

The gauge is mechanically one of the finest pieces of workmanship of its class now in the market, and the fact that it can be used continuously, that is, that it need

not be looked after every day, makes it particularly desirable where it would be inconvenient to change records every twenty-four hours; and the user can be assured that the records will continue in a legible shape whether it receives proper attention or not, which, of course, cannot generally be done in the case of gauges making a circular record.

A large amount of labor has been spent in the perfection of this gauge during the many years that it has been in use, and the fact that the gauge as now made is such an excellent piece of apparatus, warrants the Institute in recommending the award of the John Scott Legacy Premium and Medal to the inventor, Mr. Jarvis B. Edson, for the excellent development of his pressure recording gauge.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, November 1, 1893.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
H. R. HEYL, *Chairman.*

APPENDIX.

LIST OF UNITED STATES PATENTS BEARING ON THE SUBJECT OF RECORDING GAUGES, AND CONSULTED IN THIS INVESTIGATION.

Rice, No. 7,583, August 20, 1850.
Krausch, No. 36,411, September 9, 1862.
Wiegand, LeVan, No. 41,182, January 5, 1864.
Davis, No. 66,307, July 2, 1867.
Peelor, No. 113,693, April 11, 1871.
Davis, No. 152,467, June 30, 1874.
Robinson, No. 169,660, November 9, 1875.
Thomson, No. 232,156, September 14, 1880.
Stowe, No. 234,086, November, 2, 1880.
Brouardel, No. 242,260, May 31, 1881.
Thissell, No. 253,786, February 14, 1882.
Jonson, No. 265,327, October 3, 1882.
Bernstein, No. 268,383, December 5, 1882.
Jones and Glines, No. 287,684, October 30, 1883.
Jones, No. 287,685, October 30, 1883.
Jones, No. 287,686, October 30, 1883.
Richard, No. 334,613, January 19, 1886.
Shedlock, No. 336,668, February 23, 1886.
Jones, No. 340,581, April 27, 1886.

Jones, No. 343,177, June 8, 1886.
Jones, No. 344,448, June 29, 1886.
Jones, No. 345,061, July 6, 1886.
Jones, No. 348,219, August 31, 1886.
Hambleton, No. 360,291, March 29, 1887.
Hambleton, No. 389,635, September 18, 1888.
Tata, No. 408,938, August 13, 1889.
Wills, No. 409,891, August 27, 1889.
Sporton White, No. 410,214, September 3, 1889.
Herschel, No. 417,245, December 17, 1889.
Schroyer, No. 426,144, April 22, 1890.
Williams, No. 447,594, March 3, 1891.
Ayton, No. 459,863, September 22, 1891.
Seiler, No. 481,287, August 23, 1892.

[*Abstract.*]

ON THE MAXIMUM CONTEMPORARY ECONOMY OF THE HIGH-PRESSURE MULTIPLE-EXPANSION STEAM ENGINE.*

By Robert H. Thurston, LL.D.,
Director of Sibley College, Cornell University. Past President, A.S.M.E.

The paper, of which the following is an abstract, includes an account of the investigation of the economical performance of a triple-expansion steam pumping engine, designed by Mr. Irving Reynolds, in consultation with Mr. Edwin Reynolds, and built by the E. P. Allis Company, of Milwaukee, under a contract with that city; which engine is now in operation at the North Point Station, supplying the city with water from Lake Michigan. Its exceptional economy and high duty were revealed, originally, by the result of the customary "contractor's trial," made to determine whether the terms of the contract had been fufilled † and whether its acceptance by the city, with payment as

* Presented at the New York Meeting (December, 1893), of the American Society of Mechanical Engineers, and forming part of Volume XV, of the *Transactions*. Abstract prepared by the author especially for the *Journal of the Franklin Institute*.

† The guarantee was a duty of 125,000,000, with 100 pounds of anthracite coal.

agreed, should be carried out. The results of the trials made later, especially those made by the Sibley College staff, confirmed the first impression, that this engine illustrates the maximum contemporary economy of the high-pressure multiple-expansion steam engine, and the publication of this paper probably establishes this as "breaking the record" to date, and fixing the limit of efficiency of the best existing engines nearer the ideal figure than it has ever before been brought. The Milwaukee engine demands but about twenty-five per cent. more heat, steam and fuel, when doing its best work, than would the representative ideal engine, the purely thermo-dynamic machine, operating under the same physical conditions and in the same manner, as to steam distribution, as the real engine. The real engine has about seventy-five per cent. of the efficiency of the ideal. It is this fact which makes the information here presented to the reader interested in steam engineering in any of its aspects so exceptionally important. An engine which brings down the consumption of energy of heat and steam and fuel to the equivalent of 13,056 B.T.U. per hour, 217 per minute, per horse-power, to 11·678 pounds of dry steam per horse-power per hour, and to 1·25 or 1·35 pounds of fuel, giving an actual duty, watch by watch, for twenty-four hours, of 140,000,000 to 150,000,000 per 100 pounds of fuel actually consumed, with but moderate efficiency of boiler, and averaging the equivalent of 154,048,000 foot-pounds per 1,000 pounds of dry steam at the engine, not only establishes a wonderful record, but marks off an era in the progress of the steam engine. This is probably about the limit for the century, and twelve pounds of steam per horse-power per hour, a figure now known to have been approximated by several engines, may be taken as the culmination of the progress of the nineteenth century. The following abstract gives the essential facts presented in this paper, relative to this interesting and important case.

The maximum contemporary economy of the steam engine of the time has now so nearly approached the computed efficiency of its ideal thermo-dynamic representative, under similar external working conditions, that it has

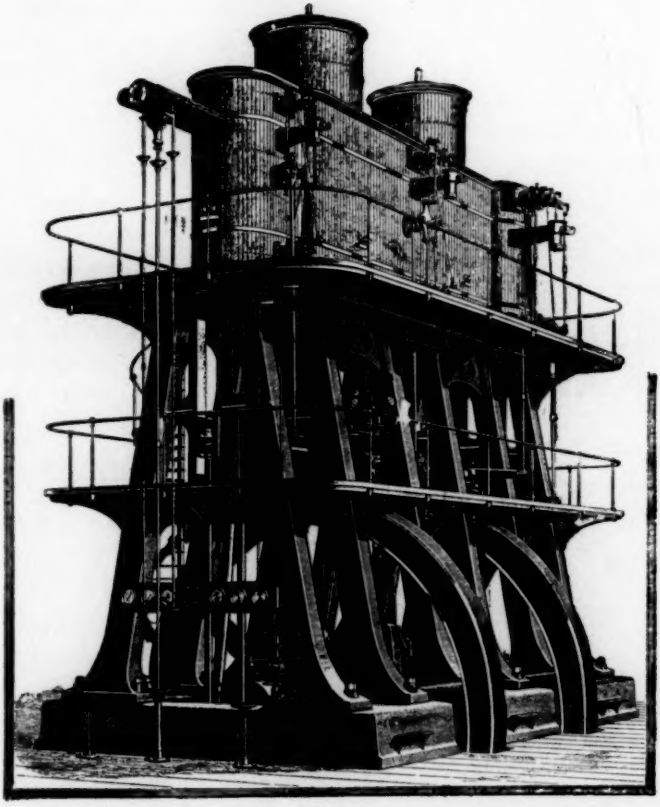


FIG. 1.—Milwaukee Triple-expansion Pumping Engine.

[From Thurston's *Manual of the Steam Engine.* John Wiley & Sons, New York.]

come to be admitted that the distance separating them, a consequence of the unavoidable and almost irreducible wastes to which the former is subject, and from which the latter is free, although still growing less, is exceedingly difficult of further reduction. The closer the approximation of the real to the ideal, the more difficult it is to further improve the machine, and the more certain it is that any considerable and rapid gain is out of the question. We have, for a century, been constantly changing the conditions exterior to the machine, in such manner as to raise the maximum efficiency of the ideal case as steadily higher and make it more difficult of attainment by the real engine; while we have as constantly and steadily reduced the defects of the latter in such manner as to make the approximation of the real to the ideal closer and closer, in spite of these obstructive circumstances. Perhaps the best view of these changing conditions and performances may be obtained by the observation of the continual gain exhibited in its history, since the days of Watt or of Newcomen, in the magnitude of the technically so-called "duty" of steam pumping engines.

With improving thermo-dynamic conditions and decreasing wastes in the engine, starting from the 5,000,000 duty of the Savery engines still existing in the time of Watt, the 12,000,000 of Smeaton's Newcomen engine of the same period, and the first figures of Watt, perhaps averaging 20,000,000 foot-pounds per 100 pounds of fuel; and tracing the improvement through the most flourishing period of Watt's work, when he attained about 30,000,000, and his final perfection of the later Cornish engines, which, still later, attained in ordinary operation 60,000,000 to 80,000,00c, we come to the period, beginning with 1860, of the successful introduction of modern forms of the high-pressure multiple-expansion pumping engine, giving duties ranging up to about 100,000,000 to 110,000,000, and to 120,000,000 in the succeeding generation and to date.

* * * * * * *

The history of this case is briefly as follows: The attention of the writer was first called to this remarkable engine

by Mr. E. D. Leavitt, who, in December, 1892, reported its performance as 12·15 pounds of water per horse-power per hour, and suggested obtaining from its designer and builders the facts relating to the plant, with a view to publication in the interests of science and of the profession. Acting at once upon this suggestion, the writer secured permission from the City Engineer's office, and from the builders and the designers of the engine, to make a special duty-trial of the machine, in the interest of all concerned and of the profession especially. The trial was to be made by the Sibley College staff, as a part of the year's work of the Department of Experimental Engineering, with every facility that either the proprietors, the builders, or Cornell University and Sibley College, could furnish. The results were to be worked up in the Sibley College laboratories, reported by the college to the designers, builders, and users of the engine, and published as soon as practicable by the writer, acting for the parties interested.

It was proposed that the trial should be made during the Easter vacation of the college, by a party to be selected, organized, and directed by Prof. R. C. Carpenter, and to include such skilled and trained observers as could best be secured from his own department, re-enforced by observers sent in by the City Engineer and by the Allis Company. Among the "crew" sent out from Ithaca were several men engaged in graduate work, seeking material for their "Masters' theses," and some undergraduates; all of whom had enjoyed exceptional opportunities and shown great skill and efficiency in work of this kind. The special desire of the writer was to secure such data as would serve for a comparison of the theoretical ideal and the real engine, such as is here attempted, which comparison had never before been made in precisely this manner or with what it was hoped would prove such unexampled completeness.

This trial was finally made as proposed, and the results proved to be even more striking and satisfactory than had been claimed by the builders or reported to the writer. The data and observations are preserved in the files of the Sibley College laboratory.

* * * * * * *

The Milwaukee engine is of the vertical triple-expansion type, with steam cylinders and parts above the bed-plate, arranged somewhat similar to those of the modern marine engine (*Figs. 1, 2, 3*). The capacity of the engine is 18,000,000 gallons in twenty-four hours, raised 160 feet, and the speed is 20 revolutions per minute, or 200 feet piston speed. The cylinders are three in number, one high-pressure, 28 inches diameter, one intermediate, 48 inches, and one low-pressure, 74 inches diameter, all having a stroke of 60 inches. The cylinders are mounted on cast-iron A frames, which rest on heavy bed-plates carrying the main shaft journals. The cylinders are steam-jacketed, having the working barrels inserted separate as "liners." The steam and exhaust valves are located in the cylinder-heads, their chests thus jacketing the latter.

The pumps are entirely below the floor. The fly-wheels perform the office simply of aiding in the regulation of the engine. Between each two cylinders is a receiver, heated by high-pressure steam. The volumes are, respectively, high pressure, 101·3 cubic feet; intermediate, 151 cubic feet. In the high-pressure and intermediate cylinders the jackets are supplied with live steam at boiler pressure; but on the low-pressure cylinder the jacket is supplied with steam which passes through a reducing valve, and which has a constant pressure of thirty-four pounds. The steam is supplied to the high-pressure jacket by a pipe leading directly from the main steam-pipe; the exhaust from this jacket supplies the jacket of the intermediate cylinder, and this is led into a trap, the overflow of which ordinarily passes into the suction of the feed-pump for supplying the boilers. The exhaust steam from the low-pressure cylinder jacket is similarly received into a steam-trap and discharged into a feed-pipe.

The exhaust valves of the low-pressure cylinders, when closed, are flush on the inside of the cylinder head, thus eliminating clearance due to exhaust ports. All the valve ports are located in the cylinder heads.

The valve gear is of the Corliss type on the high and intermediate cylinders, and a combination of Corliss steam valves and poppet exhaust valves on the low-pressure cylin-

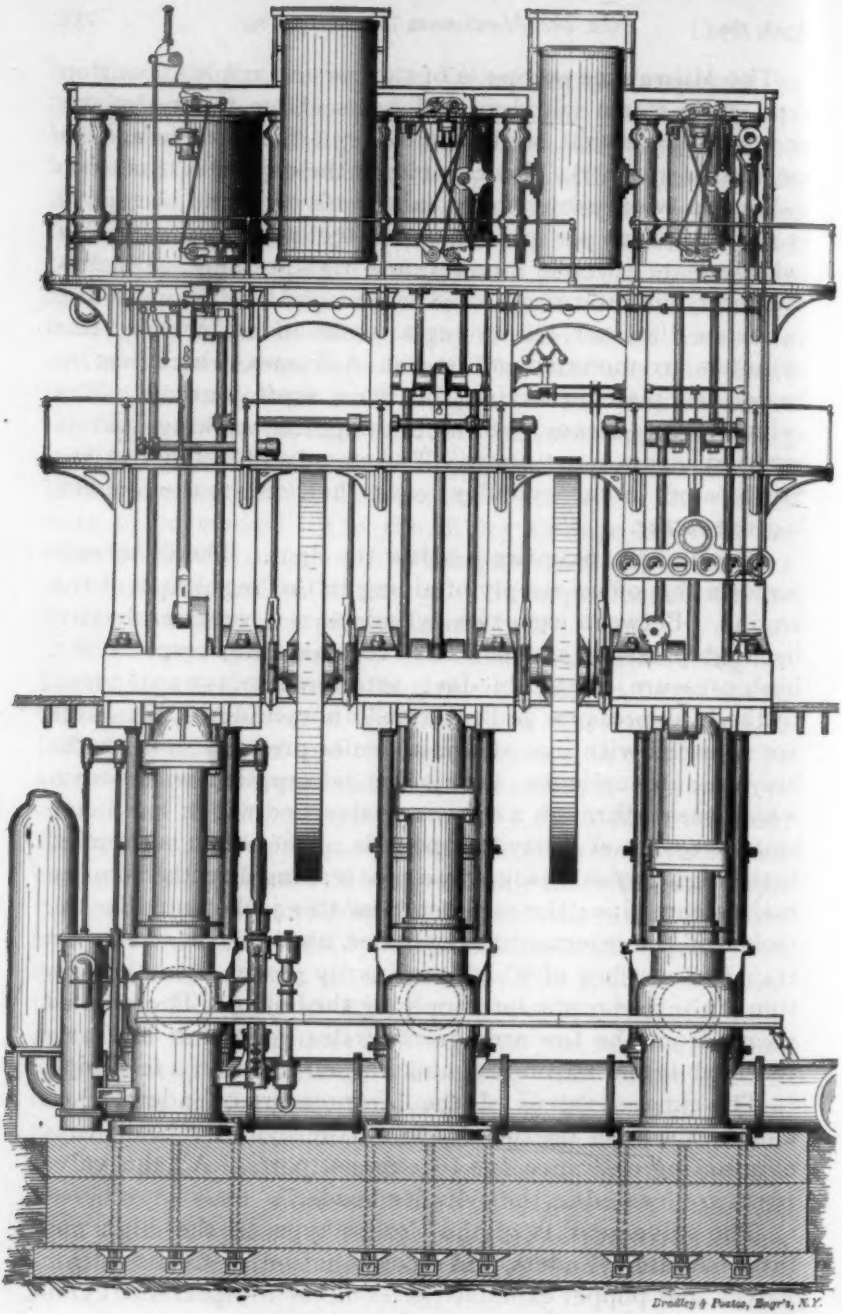


FIG. 2 —Front view of engine.

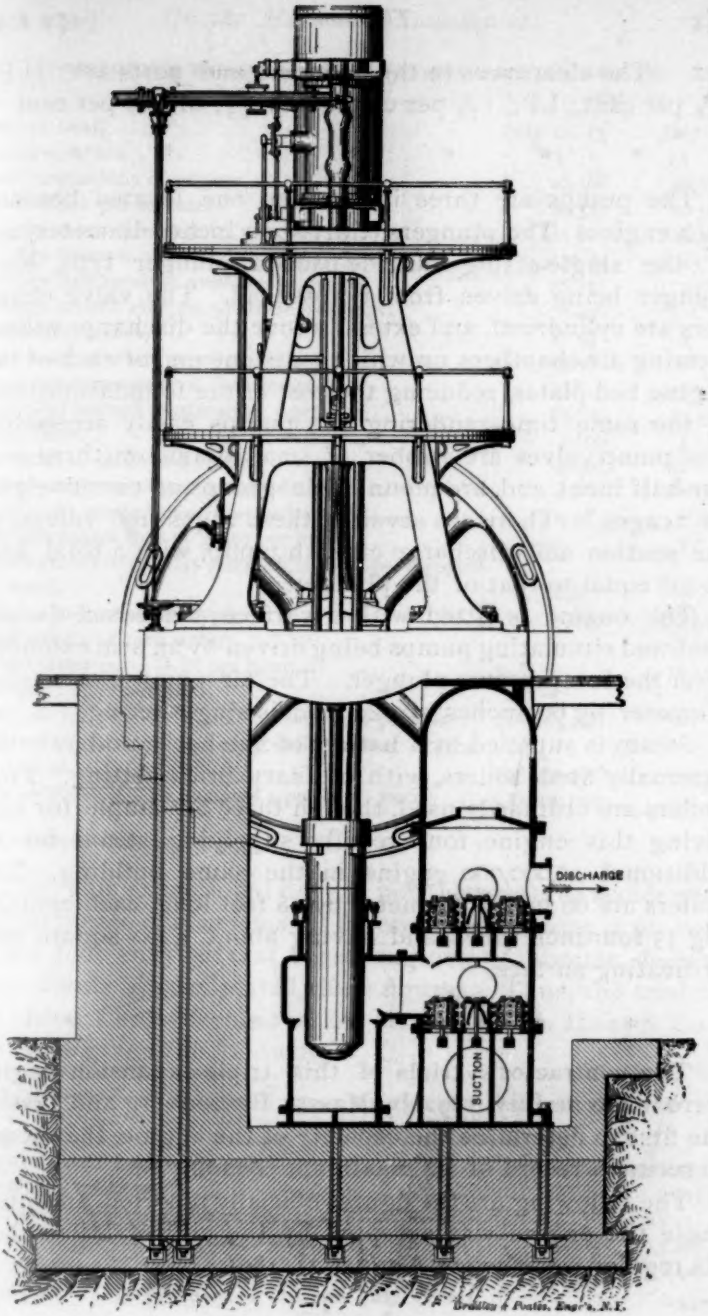


FIG. 3.—Section of pump.

der. The clearances in the cylinders and ports are: H.P., $1\frac{4}{10}$ per cent.; I.P., $1\frac{5}{10}$ per cent.; L.P., $\frac{77}{100}$ of one per cent.

* * * * * * *

The pumps are three in number, one located beneath each engine. The plungers (thirty-two inches diameter) are of the single-acting outside-packed plunger type, each plunger being driven from a crosshead. The valve chambers are cylindrical, and extend above the discharge valves, forming air chambers, on which rests one end of each of the engine bed-plates, reducing the cost of the foundations, and at the same time rendering the pumps easily accessible. The pump valves are rubber, of small diameter (three and one-half inch), and are mounted in groups of twenty-eight, on "cages." There are seven of these cages (196 valves) in the suction and discharge of each pump, with a total area about equal to that of the plunger.

The engine is fitted with a surface condenser, the air, feed, and circulating pumps being driven by an arm extended from the low-pressure plunger. The air pump is 22 inches diameter by 60 inches stroke, and is single-acting.

Steam is supplied by a battery of five horizontal, tubular, externally fired boilers, with ordinary brick setting. Four boilers are ordinarily used, though three are ample for supplying this engine, four readily supplying steam for an additional 12,000,000 engine in the same building. The boilers are 66 inches diameter by 18 feet long, each containing 55 four-inch tubes, and having about 1,200 square feet of heating surface.

* * * * * * *

The contractor's trials of this triple-expansion engine were made in July, 1892, by Messrs. Benzenberg and Lewis; the first to determine the capacity of the engine, the second to secure a record of its maximum economy.

The following are the figures officially reported, and upon these the engine was accepted by the city of Milwaukee. Its regular work began August 23, 1891.

CONTRACTOR'S TRIALS, TRIPLE-EXPANSION PUMPING ENGINE.

	1892.	
Date of trial,	July 12, 13	July 20
Duration, hours,	24	24
Total revolutions of engine,	29,566	29,524
Revolutions per minute,	20·532	20·503
Average steam pressure by gauge,	125·8	125·33
Average vacuum pressure by gauge,	13·794	13·75
Average first receiver pressure by gauge,	28·17	29·83
Average second receiver pressure by gauge,	0·406	1·10
Barometer, inches,	27·99	—
Total head of water pumped against,	153·56	—
Average temperature of feed water, F.,	130°	132°·2
Total coal burned (Anthracite, egg),	18,700	19,200
Total ashes,	2,690	3,187
Per cent. of ashes and refuse,	14·385	16·6
Actual evaporation per pound of coal,	8·76	8·758
Equivalent evaporation from and at 212°,	9·91	9·89
Coal per square foot of grate per hour,	—	7·5
Total number of gallons pumped, by plunger displacement,	18,528,657	—
Average indicated horse-power,	557,029	576,449
Total weight of feed water	—	168,163
* Feed water per I.H.P. per hour,	—	12·155
Coal per I.H.P. per hour,	—	1·387
Duty per 100 pounds of coal burned, foot-pounds,	126,865,240	—
Duty on supposition that evaporation was 10·27 from and at 212°, foot-pounds,	132,950,524	—
Duty as above if coal contains 3 per cent. water,	136,900,000	—

* No correction for moisture.

That this exceptional duty is not the result of accidental and fortunate concurrence of favorable conditions is proven by the fact that several other engines of similar design have closely approximated these figures. Thus, the trial of the three Chicago engines, by Messrs. R. W. Hunt & Co., has since given the following:*

RESULTS OF CONTRACTOR'S TRIAL OF CHICAGO PUMPING ENGINES, JULY, 1893.

Aggregate delivered horse-power,	1031·47
Mechanical efficiency,	0·9143
Aggregate indicated horse-power,	1128·15
Feed water per delivered horse-power per hour,	13·267

* Report to City Engineer of Chicago, July 5, 1893.

Feed water per indicated horse-power per hour, pounds, ...	12·13*
B.T.U. per delivered horse-power per minute, ...	244·6
B.T.U. per indicated porse-power per minute, ...	223·7
Indicated horse-power per square foot of upper grate (H furnace),	12·82
Heating surface per indicated horse-power, ...	4·35
Foot-pounds per 1,000 pounds of feed water (contract basis), . .	148,958,000
Foot-pounds per 1,000,000 B.T.U., ...	134,643,030
Foot-pounds per 100 pounds of bituminous coal, ...	118,022,900
Foot-pounds per 100 pounds of combustible, ...	128,852,500

* Equivalent, with one per cent. entrained water, to 12·03 pounds.

* * * * * * *

The Sibley College trials were inaugurated March 23d, by a preliminary organization of the crew and a practice test of several hours' duration, in which the observers were given a drill in their assigned work. The engine was examined and inspected in every part, and the whole system of apparatus was tested, to ascertain its fitness for the purposes in view.

All arrangements being found satisfactory, the final trial was proceeded with, March 25th, at 9 A.M.; was continued uninterruptedly twenty-four hours; was commenced and ended to the satisfaction of all four sets of observers, and was so certified by the representatives of the city of Milwaukee, of the builders, of the delegate from R. W. Hunt & Co., and by the official representative of Sibley College.

The weight of water delivered was computed from the plunger displacement, and the total weight for each revolution of the engine was 5229·29 pounds.* The average head pumped against was 161·84 feet. The head was measured by a pressure gauge connected to the discharge chambers of the pumps.

* * * * * * *

* This is a standard method, and was, in fact, the only method practicable at the time. The writer would always check by the use of a weir, when possible; but, in this case, the construction of the pumps was such as to make sensible slip improbable, and the pump cards are so sharp at the corners as to indicate that they ran full. The writer made a visit to Milwaukee and personally examined the engine, to satisfy himself of the fact that the valves act promptly and efficiently. Experiment, later, on an engine of similar construction, gave a slip of 0·0073. It may be taken here as undoubtedly less than one per cent.

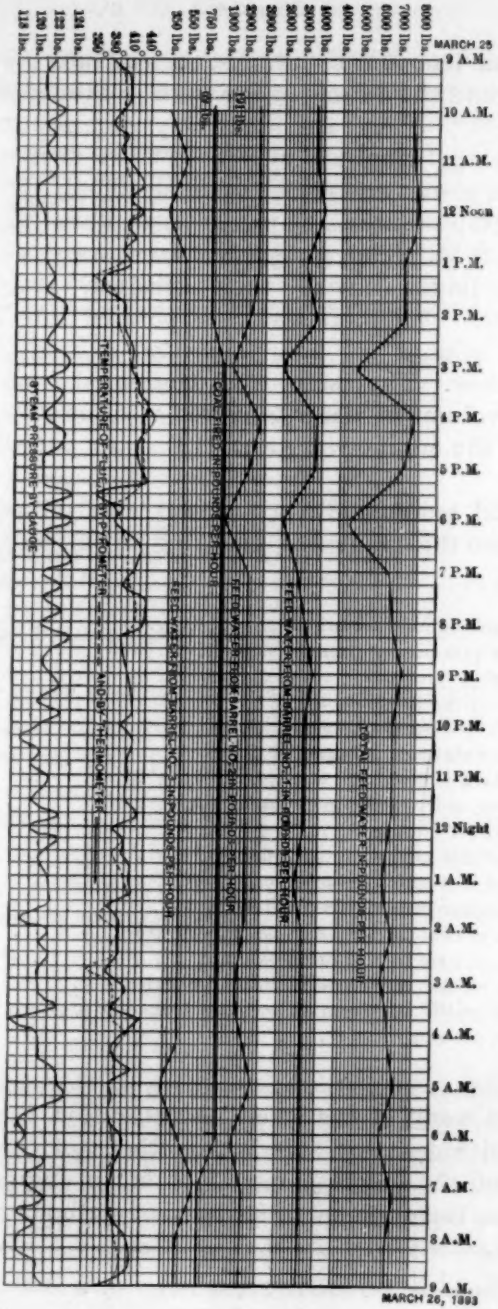


FIG. 4.—Graphical log.

The data, logs and results of this trial are given in the Appendix, and the details of the work in the report made to the builders.* They are admirably summarized in the accompanying "graphical log." As there shown, the indicated horse-power was 573·87, divided among the cylinders thus: High-pressure, 175·39; intermediate, 169·62; low-pressure, 228·86. The gauge pressures were, at the high-pressure cylinder, 121·46; first receiver, 32·43; second receiver, 1·5. The total water evaporated into dry steam was 6700·7 pounds per hour, *equivalent to 11,678 pounds per I.H.P. per hour.* The useful work computed from the pressures and volume of water delivered was 520·06 D.H.P. The friction of the engine was 52·92 H.P., 9·22 per cent. of the I.H.P.

A special test, made April 7, 1893, determined the heat rejected into the condenser, resulting as below:

Average revolutions per minute,	20·41
Average steam pressure, gauge, pounds,	121·6
First receiver pressure,	31·9
Second receiver pressure,	1·67
Vacuum below atmosphere, inches,	13·5
Temperature of ejector water,	40° F.
Temperature of discharge water,	98° F.
Depth over weir, twelve-inch notch, feet,	0·2659
Cubic feet per minute,	26·78
Pounds of injection water per minute,	1,660
Pounds of feed water per minute,	111·6
Ratio injection water to feed water,	14·9
Per cent. of heat carried off in jacket water,	9·25
Per cent. of heat carried off in exhaust,	75·10
Per cent. of heat carried off in discharge water,	15·65
Probable quality of steam in exhaust from low-pressure engine, per cent.,	84·3

The net result of the whole investigation is seen to be the establishment, by standard methods of contemporary practice, of the highest record of steam-engine duty yet obtained as the outcome of such exact methods of research.

* *Sibley Journal of Engineering*, June, 1893.

The useful work performed, measured as "duty" by the accepted standards, is:

Foot-pounds of work for 100 pounds dry coal,	143,306,470
Foot-pounds of work for 100 pounds wet coal,	135,770,000
Foot-pounds of work for 100 pounds combustible,	145,438,000
Foot-pounds of work for 1,000 pounds feed-water,	152,448,000
Foot-pounds of work for 1,000 pounds dry steam,	154,048,000
Foot-pounds of work for 1,000,000 B.T.U.,	137,656,000
Foot-pounds of work for one hundredweight coal (112 pounds),	152,630,000
Kilogrammeters of work per kilo of coal,	429,110

The thermo-dynamic results are:

Thermo-dynamic efficiency,		0·194
Heat per I.H.P. per hour, and per minute, B.T.U.,	13,056	217·6
Steam per I.H.P. per hour, pounds,		11·678
Fuel per I.H.P. per hour, pounds,		1·237
Heat per D.H.P. per hour, and per minute, B.T.U.,	14,382	239·7
Steam per D.H.P. per hour, pounds,		12,864
Fuel per D.H.P. per hour, pounds,		1·364

Were these engines attached to boilers evaporating ten pounds instead of nine, the fuel-rate would be, per I.H.P., 1·168 pounds, and per D.H.P., 1·286, or about $1\frac{1}{8}$ and $1\frac{1}{4}$ pounds, respectively.

The efficiency above given is 0·668, or two-thirds, that of a Carnot cycle working through the same range of temperatures and pressures. It is equal to $0{\cdot}194/0{\cdot}252 = 0{\cdot}77$ of the thermo-dynamic efficiency for the Rankine cycle of the ideal case.

* * * * * * *

The distribution of the energy supplied to the engine, during the trial, can now be readily determined for comparison of the real with the ideal case. The ideal engine, under similar circumstances, would have an efficiency of about 0·25, and would require 9·25 pounds of steam, nearly a pound of fuel per horse-power per hour. We find, from the records of the trial, that of all the energy developed in the cylinders,

9·22 per cent. was wasted in friction. In summary, we obtain the following figures:

DISTRIBUTION OF ENERGIES.

Part of Total Energy Supplied.	Per Cent.	Per D.H.P. per Hour.	
		B.T.U.	Pounds Steam.
Thermal and thermo-dynamic wastes,	80·57	11587·51	10·455
Dynamic, or friction, waste,	1·73	248·81	0·222
Useful work,	17·70	2545·61	2·187
Total thermo-dynamic transformation,	19·43	2794·42	2·409
Total from boilers,	100·00	14,382	12·864

APPENDIX.

Dimensions, Logs, Data and Results of Trial of the Milwaukee Pumping Engine.

DIMENSION OF BOILERS.

Length,	18 ft.
Diameter,	66 ins.
Grate,	5 ft. long, 5 ft. 4 ins. wide.
Grate surface,	26·65 sq. ft.
Tubes in each boiler, 55,	diameter 4 ins.
Area of tubes in each boiler,	4·68 sq. ft.
Water-heating surface,	1,216 sq. ft.
Ratio of heating to grate surface,	35
Height of chimney,	125 ft.
Area of chimney,	12·566 sq. ft.
Total grate surface of the four boilers,	106·6 sq. ft.
Total heating surface,	4864·0 sq. ft.
Bottom of gauge glass to bottom of boiler shell,	3 ft. 1½ ins.

BOILER TEST.

Duration of test,	24 hrs.
Barometer, inches of mercury,	29·54
Atmospheric pressure, pounds per square inch,	14·5
Steam gauge, corrected (at engine),	121·6
Draft gauge, inches of water,	0·4025
Absolute steam pressure,	136·1 lbs.
External air, temperature degrees F.,	25·71
Boiler room, temperature degrees F,	50
Flue, { Thermometer in top, degrees F.,	406·02
Flue, { Pyrometer in centre, degrees F.,	403·02
Feed water,	97
Steam,	350·6

Fuel.

Total coal consumed, pounds,	18,234
Moisture in coal, per cent,	5·25
Dry coal consumed,	17,277
Total ash, dry, pounds,	255
Total ash, dry, per cent. of dry coal,	1·47
Moisture and ash, per cent. of wet coal,	6·65
Total combustible, pounds,	17·022

Fuel per Hour, Pounds.

Actual,	759·75
Dry coal,	719·84
Combustible,	709·25
Actual coal per square foot of grate,	7·15
Dry coal per square foot of grate,	6·76
Combustible per square foot of grate,	6·65

Calorimeter.

Temperature of steam in calorimeter, degrees F.,	284·6
Back-pressure in calorimeter, inches of mercury,	1·9
Quality of steam,	98·95
Per cent. of entrained water,	1·05
Number of minutes calorimeter was open,	114
Steam used in calorimeter, pounds,	208·5

Feed Water.

Total weight of water used, pounds,	162,864
Excess of water in boiler at end of run, pounds,	131
Total evaporated dry steam, pounds,	161023·2
Factor of evaporation. (Equivalent value of one pound wet steam to one pound dry steam from and at 212° F.)	1·154
Total equivalent evaporation from and at 212° F., pounds,	187,794

Feed Water per Hour, Pounds.

Actual amount used, pounds,	6780·5
Evaporated dry steam,	6709·4
Equivalent evaporated from and at 212°,	7,710

Evaporation per Pound of Coal, Pounds.

* Apparent, feed water 97°, steam 121·4,	8·906
† Actual to dry steam,	8·81
Equivalent from and at 212°,	10·27

Evaporation per Pound of Dry Coal, Pounds.

* Apparent, feed water 97°, steam 121·4,	9·425
Equivalent from and at 212°,	10·72

Evaporation per pound of Combustible, Pounds.

* Apparent, feed water 97°, steam 121·4,	9·56
Equivalent from and at 212°,	10·88

* Uncorrected for calorimeter.

† Corrected for calorimeter.

Evaporation per Hour—Per Square Foot of Grate.

Actual, uncorrected for moisture, pounds,	63·6
Equivalent from and at 212°, pounds,	73·2

Per Square Foot of Water-heating Surface.

Actual, uncorrected for moisture, pounds,	1·505
Equivalent from and at 212°, pounds,	1·73

Per Square Foot of Least Draft Area.

Actual, uncorrected for moisture, pounds,	373
Equivalent from and at 212°, pounds,	429

Horse-power.

On basis of 30 pounds, from 100° F. to 70 pounds pressure,	223·5
Builder's rating,	400
Ratio of boiler horse-power to capacity, per cent.,	55·7

Efficiency of Boiler.

(*A*) Heat generated per hour on basis of 14,500 B.T.U. per pound of combustible,	10,285,125
(*B*) Heat absorbed by steam per hour, B.T.U.,	7,554,833
Efficiency of boiler, (*A*)÷(*B*), per cent.,	73·45

TRIPLE-EXPANSION PUMPING ENGINE.

Dimensions.

Length of stroke of each piston,	60 ins.
Diameter of high-pressure cylinder,	28 ins.
Diameter of intermediate-pressure cylinder,	48 ins.
Diameter of low-pressure cylinder,	74 ins.
Diameter of piston rod in each cylinder,	4 ins.
Number of piston rods in each cylinder,	6
Clearance of high-pressure cylinder per cent.,	1·4
Clearance of intermediate-pressure cylinder, per cent.,	1·5
Clearance of low-pressure cylinder, per cent,	0·77
Volume of first receiver,	101·3 cu. ft.
Volume of second receiver,	181 cu. ft.
Number of reheater pipes, first receiver,	57
Number of reheater pipes, second receiver,	35
Diameter of reheater pipes,	2 ins.
Number of single-acting water plungers,	3
Diameter of each,	32 ins.
Diameter of single-acting air pump,	20 ins.
Diameter of single-acting plunger feed pump,	2¼ ins.
Diameter of single-acting air compressing pump,	2¼ ins.
Diameter of double-acting circulating pump,	7½ ins.
Stroke of all pump plungers,	60 ins.
Distance from centre of pressure gauge to centre of pump chamber,	19·8 ft.
Distance from bottom of well to centre of pump chamber,	20 ft.

Area of Piston, Square Inches.

	Top.	*Bottom.*
Area of piston, high pressure,	615·745	590·621
Area of piston, intermediate pressure,	1809·562	1784·429
Area of piston, low pressure,	4300·85	4275·72
Area of each pump plunger,	804·2496 sq. in.	5·585 sq. ft.
Total volume delivered per revolution by one plunger,		27·9253 cu. ft.
Total volume delivered per revolution by three plungers,		626·688 gals.
Total weight delivered per revolution by three plungers,		5229·291 lbs.

ENGINE TEST—*Results and Data.*

Duration of test,	24 hrs.

Average Temperatures.

Water at pump well, F.,	34°
Feed water to boiler,	97
Discharge from air pump,	105·4
Calorimeter (1·9 inches back-pressure),	284·5
Engine room,	69·9
External air,	25·71

Average Pressures

Barometer, inches,	29·54
Barometer, pounds,	14·5
Gauge at throttle,	121·45
Absolute pressure at engine,	135·94
Vacuum gauge, pounds,	13·84
First receiver gauge, pounds,	32·43
Second receiver gauge, pounds,	1·3
High-pressure jacket, pounds,	121·40
Low pressure by gauge, pounds,	56·47
Suction head by float, feet,	10·77

Revolutions.

Total number,	29,252
Per hour,	1218·8
Per minute,	20·314
Quality of steam, per cent.,	98·95
Moisture in steam, per cent.,	1·05

Feed Water and Dry Steam.

Total feed water to boiler, pounds,	162,864
Excess in boilers at end of run, pounds,	131
Steam used by calorimeter (114 min.), pounds,	208·5
Total wet steam to engine,	162524·5
Total dry steam to engine,	160818·1
Wet steam to engine per hour,	6771·8
Dry steam to engine per hour,	6700·7
Heat in one pound wet steam above 105·4 F., B.T.U.,	1106·26
Heat supplied to engine per hour, B.T.U.,	7,493,444
Heat supplied to engine per minute, B.T.U.,	124890·7

Total wet steam used in jackets,		15,054
Wet steam used in jackets per hour,		627·3
Per cent. of total steam used by jackets,		9·25
Indicated Horse-power.		
High-pressure cylinder,	Top,	87·54
	Bottom,	87·85
		175·39
Intermediate,	Top,	88·84
	Bottom,	80·78
		169·62
Low,	Top,	116·23
	Bottom,	112·63
		228 86
Total,		573·87
Delivered horse-power,		520·96
Friction horse-power,		52·91
Friction horse-power, per cent.,		9·22
Dry steam per I. H. P. per hour,		11·678
B.T.U. per I.H.P. per minute,		217·6

Relative Volumes of Cylinders.

High-pressure,	1	1
Intermediate,	2·95	3·01
Low,	6·95	7·01
Total number of expansions,		19·55

PUMP TEST.

Duration,	24 hrs.
Temperature of water pumped, F.,	34°
Weight per cubic foot,	62·42
Pounds of water lifted per revolution,	5229·2917
Water pressure in pounds,	56·473
Delivery head in feet,	131·275
Distance from delivery gauge to centre of pump, feet,	19·8
Suction head in feet,	10·77
Total head in feet,	161·845
Revolutions per hour,	1218·8
Foot-pounds of work per hour,	1,031,520,000
Kilogrammeters per hour,	142,556,000
Wet coal per hour, pounds,	759 75
Dry coal per hour, pounds,	719·8
Kilograms of coal per hour,	332·23
Combustible per hour, pounds,	709·25

Duty.

Foot-pounds of work for 100 pounds of dry coal,	143,306,470
Foot-pounds of work for 100 pounds of wet coal,	135,770,000
Foot-pounds of work for 100 pounds of combustible,	145,438,000

Foot-pounds of work for 1,000 pounds of feed-water,	152,448,000
Foot-pounds of work for 1,000 pounds of dry steam,	154,048,000
Foot-pounds of work for 100,000,000 B.T.U.,	137,656,000
Foot-pounds of work for one hundredweight coal (112 pounds),	152,630,000
Kilogrammeters of work per kilo of coal,	429,110

Capacity.

Cubic feet per revolution $3 \times 27{\cdot}9253$,	83·7759
Gallons per revolution,	626·688
Cubic feet per hour,	102112·5
Gallons per hour,	763,807
Cubic feet for 24 hours,	2,450,940
Gallons for 24 hours,	18,331,364

PRINCIPAL QUANTITIES OF BOILER AND PUMP TEST FOR EACH WATCH OF FIREMAN.

Number of Watch.	*A.*	*B.*	*C.*	*D.*	*Total or Averages.*
Duration of hours,	5	8	8	3	24
Coal fired,	3,591	6,284	6,284	2,075	18,234
Coal per hour fired,	718	785·5	785·5	691·60	759·75
Estimated excess in furnace,	—35	110	150	45	—
Coal per hour burned,	725	775	776	730	—
Dry coal (cor. 5·25 per cent.),	688	735	736	693	719·8
Temperature feed water,	—	—	—	—	—
Steam pressure at engine,	121·43	122·14	121·29	120·41	121·46
Barometer, inches,	29·55	29·53	29·52	29·577	29·537
No. barrels water per watch:					
Bbl. No. 1 net wt. 400¼	45	60	63	24(—20)	192—20
Bbl. No. 2 net wt. 386¼	45	60	62	24	191
Bbl. No. 3 net wt. 173½	13⅛	24	23	10	70⅛
Wt. of water, Bbl. No. 1,	18,011	24,016	25,216	9,586	—
Bbl. No. 2,	17,016	23,595	23,978	9,282	—
Bbl. No. 3,	2,874	4,164	3,591	1,735	—
Total feed water.	37,301	51,775	53,185	20,603	162,864
Excess in tank, end watch,	785	750	300	—	—
Excess in boilers (change in ht. on gauge glass, in.),	1·75	0·16	—0·215	0·08	—
Excess in boilers, pounds,	2,667	259	—365	131	131
Total evaporation during watch,	33,849	54,218	54,357	20,517	54,354
Evaporated per hour,	6,770	6,777	6,795	6,805	6780·5
Evaporated per lb. of coal, actual,	9·36	8·74	8·74	9·35	8 906
Calorimeter open, minutes,	45	44	—	25	114
Steam used by calorimeter, lbs.,	82	81	—	45·5	208·5
Quality of steam per cent.,	98·95	98·95	98·95	98·95	98·95
Temperature of water pumped,	34	34	34	34	34
Water pressure in lbs.,	56·775	56·86	56·96	57·08	56 903
Delivered hd. in ft. (2·307 ft. = 1 lb.),	130·96	131·25	131·31	131·56	131·275
Distance centre pump to gauge,	19·8	19·8	19·8	19·8	19·8
Suction head in feet,	10·7	10·594	10·398	11·005	10·77
Total head in feet,	161·46	161·644	162·008	162·365	161·845
Millions of foot lbs. per hour,	1025·008	1032·6	1032 723	1034·995	1031·520
Actual duty from 100 lbs. dry coal burned, millions foot lbs.,	150·06	140·08	140·02	150·07	143·30647
Actual duty from 100 lbs. coal burned, millions foot lbs.,	142·7106	133·238	133·0827	142·7	135·77
Duty from 1,000 lbs. of steam, millions foot lbs.,	152·45	152·4	152·3	152·5	152·448

THE ADULTERATION OF FOOD.*

BY H. W. WILEY,
Chemist of the U. S. Department of Agriculture.

Barnum made a colossal fortune by acting on the principle that Americans like to be humbugged. There is something soothingly seductive in being led to the circus by lurid posters showing unattainable attitudes of impossible monsters. This attractiveness is increased by the knowledge that, like the limited express, it implies an extra charge. The public would rise with unanimous execration were it to attend a circus where side shows were not known and the *post ludum* concerts were free. Were the feats of legerdemain of the mystic Hermann actual performances of supernatural powers, they would lose for us half their charm. To be cheated, fooled, bamboozled, cajoled, deceived, pettifogged, demagogued, hypnotized, manicured and chiropodized are privileges dear to us all. Woe be to that paternalism in government which shall attempt to deprive us of these inalienable rights. There is no point on which the average American is more sensitive in respect of legal restriction, than in those instances in which the law interposes to prevent him from making a fool of himself. Only after a long struggle has a distinguished citizen of your city, now in public life, been able to prevent the mails from paying the expenses of the delta of the Mississippi. Only the other day, in New Orleans, I read in the lottery advertisement, that the ticket drawing the last capital prize of $75,000 had been sold in Washington, Philadelphia and Kalamazoo. This all doubtless comes from the fact that in this country each one of us is just as good as the next, a condition of affairs, which, in true Gilbertian humor, has been touched off in the distich:

> "When everybody's somebody,
> Nobody's anybody;"

* A lecture delivered before the Franklin Institute.

therefore we should not be surprised at the pertinent inquiry of why A, being no better than B, should interfere with B when B wants to get drunk or buy a lottery ticket.

In regard to the character of what we eat and drink, we find the same unwillingness to be watched over and protected.

A few days ago in Chicago I went out to the Union Stock Yards to look at the process of meat inspection. From each carcass of pork intended for exportation is taken a sample of the flesh and this is carefully examined for trichinæ. "Do you often find diseased samples?" I asked. "Yes," said the attendant, "from one to two per cent. of all the samples examined is found infected." "Could I see a sample of that kind?" "Certainly. Has anyone a trichinosed sample in the microscope?" A pretty girl microscopist held up her hand. I looked and saw for myself the curled and coiled serpent ready for a strike. How I congratulated that lucky sarcophagous Teuton who had been saved from a horrid death by the fairy fingers and sure blue eyes of the trichinæ girl. "What do they do with these infected carcasses?" A shrug of the shoulders led me to believe that they were sent to soap factories as they doubtless are, and this was followed by the expression, "But Americans don't eat raw pork," and I am led to suppose from this that trichinæ are really very good and nice when well broiled. Next morning, when I ordered ham for breakfast, I asked the waiter to have it cut thin and broiled crisp. Even then when it was brought in I could not help thinking that it looked like a bretzel.

That distinguished jurisconsult and patriot, Senator Paddock, of Nebraska, during the first session of the present Congress, after years of futile struggle, succeeded in having the Senate pass what is known as the Pure Food Bill, but it seems from the provisions of this bill that the Congress of the United States has only power to protect the foreigner, the disfranchised and the Indian not taxed. The provisions of the bill are confined to the Territories and the District of Columbia and to interstate commerce. Mild as are the penalties of the bill, allowing the citizens of any

State to make a dessert and call it peas if they like, yet it has been left unpassed in the House of Representatives.

The Paddock Pure Food Bill, to summarize it briefly, has for its purpose the protection of commerce in food products and drugs between the several States, the District of Columbia, the Territories of the United States and foreign countries, and the Secretary of Agriculture is authorized to make the necessary rules for carrying out the objects of the bill. He is authorized to cause to be punished, through the proper courts, any one introducing in any State or Territory, or the District of Columbia or from any foreign country any article of food or drugs which is adulterated or misbranded. The act says that the term "food" shall include all articles used for food or drink by man, whether simple, mixed or compound. In the case of food or drink, an article shall be deemed to be adulterated if any substance or substances has or have been mixed and packed with it so as to reduce or lower or injuriously affect its quality or strength, so that such product when offered for sale shall be calculated to deceive the purchaser; further, if it contain any inferior substance or substances substituted wholly or in part for the article, or if any valuable constituent of the article have been wholly or in part abstracted, or, if it be an imitation of, and sold under the specific name of, another article, or if it be mixed, colored, powdered or stained in a manner whereby any imperfection therein shall be concealed, or if it contain any added poisonous ingredient or any ingredient which may render such article injurious to the health of the person consuming it. Further, the food is declared to be adulterated if it consist of the whole or any part of a diseased, filthy, decomposed or putrid animal or vegetable substance or any portion of an animal unfit for food, provided that an article of food shall not be considered adulterated if it be a mixture or compound sold under its own distinctive name, or an article labelled, branded or tagged so as to plainly indicate that it is a mixture, compound, combination or blend.

It will be seen by the above provisions that the bill is very far-reaching in its character, and it contains also the

proper penalty for enforcing its operation. This bill passed the United States Senate on March 9, 1892. Mr. Paddock, in concluding his speech in advocacy of the bill, used the following words:

"In the name and in the interest of public morality, I appeal to you to set legislative bounds, beyond which the wicked may not go with impunity in this corrupt and corrupting work. Let us at least attempt to perform our part in the general effort to elevate the standard of commercial honesty which has been so disgracefully lowered by these deceptions, frauds and robberies, the malign influence of which is everywhere present, everywhere felt.

"Let us help by our action here to protect and sustain in his honorable vocation the honest producer, manufacturer, merchant and trader, whose business is constantly menaced and often ruined by these unscrupulous competitors, who by their vile and dishonest arts, manipulations and misbrandings are able to make the bad and impure appear to be the pure and the genuine; thus, by a double deception, both as to quality and price, making the worse appear the better choice to the unintelligent mass of purchasers.

"In the interest of the great consuming public, particularly the poor, I beg of you to make an honest, earnest effort to enact this law. At best a great multitude of our people are oppressed by a fear, a never-absent apprehension, which they carry to their work by day, and to their beds by night, that perhaps at the end of the following day, or week, or month, their ends may fail to meet. Under the strain of this grim menace life itself becomes a burden almost too grievous to be borne. But the thought of helpless wife and children, whose sole dependence he is, renews the courage of the wage-worker from day to day, and so he struggles on, praying and hoping to the end.

"These, Mr. President, are the men, and these the women and children, for whom, before all others, I make this appeal. If you could save to these the possible one-third of the nutritious element of their food supplies which is extracted to be replaced by that which is only bulk, only the form and semblance of that of which they are robbed by the dishonest

manipulator and trader, you would go a long way toward solving the great problem of the laboring masses—whether for them it is "better to live or not to live," whether it is better to bear the ills they have, rather than fly to others that they know not of, that lie beyond in the realm of governmental and social upheaval and chaos.

"There is a good deal in the way of comic "asides" as the momentous social drama which holds the boards at this time, and whose *dramatis personæ* are the so-called common people, rapidly advances to the epilogue. Be not deceived! the storm doth not abate. It is ever rising. Its violence is ever increasing. Take heed when the people demand bread that you continue not to give them a stone, lest the angry waves of popular discontent may sometime, perhaps in the near future, rise so high as to overwhelm and engulf forever all that we most greatly value—our free institutions, and all the glories and hopes of our great Republic—which are not ours alone, but which belong—and, if they are preserved and shall permanently endure, will be an ever-continuing blessing—to all mankind."

This Pure Food Bill has received the unanimous support of nearly every agricultural organization in the United States. It has been opposed by a number of manufacturing establishments interested in the production of drugs and mixed foods, and also by those largely interested in the manufacture of substitutes for lard. If adopted it can at once be seen that it would do away with the necessity of the oleomargarine law, which is a special form of legislation and like all special legislation must be open to many objections.

As before stated, the national law, as indicated above, does not protect the citizen of any State against an adulterated food which is manufactured and sold within the State. Such police power must be left wholly to the several States. Many of the States already have laws on their statute books dealing with the subject of food adulteration. These laws, however, are for the most part, inoperative, and, not being based on a common plan, would naturally not secure, even when fully enforced, the same degree of protection in all States. What is needed for a complete legal protection

of the people against adulterated foods is not only the enactment of the Paddock Pure Food Bill but a similar enactment of similar scope and aim for each of the several States.

Among the various States which have laws on the subject may be mentioned Illinois, which has an act to prevent and punish the adulteration of articles of food, drink, and medicine, and the sale thereof when adulterated. There is also a special law preventing the adulteration of butter and cheese.

Iowa has a statute, entitled an act to prevent deception in the manufacture and sale of imitation butter and cheese. One of the provisions of this law is that no keeper of a hotel, boarding-house, restaurant or other public place of entertainment shall knowingly place before any patron, for use as food, any imitation butter or imitation cheese unless the same be accompanied by a placard containing the name in English of such article printed in plain Roman type. Iowa also has a special law in regard to the adulteration of milk.

Maine has a food law to prevent the manufacture and sale of adulterated lard. Maine also has a general law on the adulteration of food and drinks.

Maryland has a statute to provide for the prevention of the adulteration of articles of food and drink and the sale thereof when adulterated or unwholesome. The enforcement of this law is placed largely in the hands of the State Board of Health.

Perhaps the best of the State laws concerning adulteration, are those of Massachusetts, the statutes of which provide "that no person shall within this Commonwealth, manufacture for sale, offer for sale, or sell, any drug or article of food which is adulterated within the meaning of this law." The law of Massachusetts is, in all essential particulars, that of the Paddock Pure Food Bill, of course, with such variations as are necessary in the enactment of a State law as compared with a Federal law. The law of Massachusetts is especially effective as regards the sale of adulterated milk and other adulterated food and has

a system of State inspection which has already reduced the percentage of adulteration of such articles to a very low figure. Monthly returns are made by the inspectors and analysts of foods and drugs. The report for the month of October, which is the latest one, contains the results of the inspection of milk, butter, cheese, olive oil, vinegar, spices, cream of tartar, molasses, maple sugar, maple syrup, honey, tea, coffee, confectionery and miscellaneous articles and drugs. The total number of samples examined was 610; the number found to conform to the legal standard was 428, and the number of samples varying from the legal standard; that is, adulterated within the meaning of the act, 182. The percentage of the adulteration was 29·8. The actual percentage of adulteration is very much less than this, for it is only suspicious articles of food to which the attention of the Board is directed. Certain staple products, such as sugar, flour, and the various cereal products, are very rarely adulterated and receive but little inspection. The work of the Board is, therefore, mainly devoted to the inspection of such articles as have been found, by several years of experience, to be especially liable to adulteration. Eleven actions were brought in the courts during the month for violation of the Food and Drugs Act. Five were for the violation of the statute relating to the sale of milk; two of coffee; one each of honey, cream of tartar, cloves and pepper. In all of the eleven cases conviction followed and fines of $247 in all were imposed. The cities and towns from which samples of food were collected during the month, were Boston, Worcester, Lowell, Cambridge, Springfield, Lawrence, Somerville, Salem, Chelsea, Malden, Newton, Taunton, Waltham, Pittsfield, Brookline, Charlton, Greenfield, Hyde Park, Lee, Marblehead, Milton, Natick, North Adams, Orange, Stoneham, Stoughton and Ware.

The case of Massachusetts is given somewhat at length on account of the excellence of the system of inspection. It shows what a State law can accomplish when wisely made and honestly enforced. In the one item of milk alone, it would be difficult to estimate the amount which has been saved to consumers by the strict enorcement of the law which

requires the milk sold to contain a certain amount of total solids and fat.

Time remains only to mention the other States which have laws of some kind on the subject of adulteration. These States are Michigan, Minnesota (which has a series of good laws, both special and general), New Hampshire, New Jersey (which also has a good system of laws), New York, Ohio (also with a fairly good system), and Pennsylvania, which divides its law into three sections; the first relating to liquors, I suppose because this is the most important of the foods of this State; the second to food adulteration in general and the third especially to dairy products. The weakness of the Pennsylvania law is not so much in the character of the provisions relating to the sale of foods as in the method of securing their enforcement. It does not provide for any system of inspection as does the law of Massachusetts; and no law relating to the adulteration of food is of any value whatever as a protection to the community unless a rigid system of constant inspection is provided for. The Pennsylvania law declares that the addition of water or of ice to milk is an adulteration, and any milk obtained from animals fed on distillery waste is declared to be impure and unwholesome. The removal of the cream is also declared an adulteration. The law prevents the manufacture of any substance provided to take the place of pure butter fat. This is not a restriction on the sale of an adulterated butter, but is a total prohibition of the manufacture and sale of any substitute for butter, even if it be sold under its own proper name.

Continuing the list of States with laws against the adulteration of food, we have next Virginia and Wisconsin. The latter State has a very good law, which not only has a general provision but also enters into detail, especially in regard to dairy products, describing what shall be considered pure milk, or establishing a standard thereof, and stating how an adulteration of milk shall be proved, and how adulterated honey shall be marked. It contains penalties for the sale of unwholesome provisions and items in regard to the adulteration of foods and drugs, fraud in dairy

manufactories, the form of label to be placed on dairy products, the strength of vinegar, etc.

It is hardly patent to this lecture to refer to foreign countries, but it may be said that in general the best laws in this country, national and federal, are based on the English food and drugs act, which is entitled an act to make better provision for the sale of food and drugs in a pure state. This became a law on the 11th of August, 1875.

The laws of the continental countries of Europe are also in the main effective, but contain such a multitude of minutiæ as would render them very burdensome if enacted in this country. The English law has been in operation long enough to prove its efficiency, and under it hundreds of convictions for the sale of impure foods and drugs have been secured.

The Canadian law is essentially the same as that of England, although not so comprehensive.

The States not mentioned in the above list have, so far as could be acertained, no laws relating to the adulteration of foods. At least they were not reported, although inquiries were sent to the Secretary of State of each State in the Union for information in regard to this matter.

Many municipalities also have local laws applying to the sale of adulterated foods. These laws are mostly of a specific nature and apply chiefly to dairy products. There would be no time here to even mention the cities having local laws on this subject, but there are now very few large cities in the country which do not at least have some kind of milk inspection.

Lying at the root of the question of food adulteration is the inquiry, what is meant by pure food? In the laws which have been enumerated, attempts have been made to legally decide what pure food is. Divested of all legal technicality, pure food is a wholesome article of food or drink which is sold and consumed under its proper name. With each particular article there must be established a separate standard which a consensus of experience with a great number of known pure substances in that list shows to be required. For instance, take the case of

milk, which is one of the most common articles of food and perhaps has been more generally adulterated than any other one. Analyses made all over the world on hundreds of thousands of samples of healthy cow's milk, have shown that the average content of solids therein is practically nearly thirteen per cent. A normal milk which falls below this standard shows some peculiarity in the animal giving it, either an incipient disease, deficient nutrition, or some idiosyncrasy. The mixed milk of a herd of healthy animals will rarely fall below this standard. For this reason the standard of twelve and one-half per cent. of total solids in milk has been adopted in most countries having laws on the subject. In some cases the benefit of the doubt is given to the vendor, and a standard is fixed at twelve per cent. Now of these total solids a certain quantity in normal milk must be butter fat. It is not often that the butter fat of a perfectly healthy cow's milk falls below three per cent of the total weight of the milk. It is much more apt to be three and one-half per cent.; hence, in fixing a standard of pure milk not only must the percentage of solids be given, namely, twelve or twelve and one-half per cent., as the case may be, but also the quantity of fat contained therein. This percentage varies in different laws from two and three-fourths to three and one-half per cent.

In a similar method the standard of purity of any other article of food must be determined by a careful examination of pure samples from all quarters and by then fixing a standard below which an article must be regarded as suspicious or adulterated.

As a distinction between a pure and an adulterated article take the cases of butter and oleomargarine. Pure butter, for instance, must be clean, sweet, wholesome and made of the fat of cow's milk and must contain only a certain proportion of water, curd and salt. Oleomargarine may be as sweet, clean and wholesome as the butter mentioned above, yet when sold as butter it is clearly not pure food, but a a spurious article.

Again, when the housewife buys lard it is supposed that

the article she obtains has been made from the fat of healthy, freshly slaughtered hogs, carefully selected and cleaned and rendered in clean kettles or tanks. Cotton-seed oil and beef tallow, in respect of cleanliness, nutritive properties and wholesomeness may equal and even excel pure lard, but the admixture of these articles with hog's lard, or their sale as such without the knowledge of consumers, is clearly a fraud and an adulteration.

From a practical point of view, food adulteration may be considered under two general aspects, namely:

(1) Adulteration harmless to health and practised merely for cheapening the article or making it more attractive to the sight or taste.

(2) The addition to a food or drink of substances positively injurious to health.

Such substances are added chiefly as preservatives or for the purpose of coloring or decolorizing, or for the purpose of giving a particular flavor or taste. As a rule, they are added in minute quantities. In fact, the proportion of such substances is usually so small that a moderate or intermittent use of food so treated may not produce any great injury to the system. The continued use of such articles, however, must end in the impairment of the general health and sometimes in permanent injury.

In the latter class of adulterations must also be included those injurious substances naturally arising from the decay of wholesome foods, or from the development of noxious substances in canned foods, or from the formation of poisonous salts by the action of the canned foods on the solder and tin of cans. Such materials, while not intentionally added, are, nevertheless, adulterations within the true scope and meaning of the term as applied to foods. In other words, it is not necessary to prove intent in order to establish the fact of adulteration. Any food which is not what it purports to be, which contains any unwholesome or poisonous ingredient, or which has any artificial coloring or facing material, is, to all intents and purposes, adulterated.

There is one legal exception to the above classification, namely, the use of annatto in coloring butter. The national

oleomargarine law, applied to the Territories, the District of Columbia and to interstate commerce, permits an artificially colored butter to be passed as genuine, and I believe most State laws referring to this subject contain the same provision. Indeed, in some States oleomargarine exposed for sale is required by law to be stained pink or some other color distinctive from yellow, and such a stain, while an actual adulteration, could not be classed as illegal.

There is still another form of fraud in food which may be defined as a negative adulteration. It consists in extracting from a food part of some valuable ingredient, and selling the residue as the genuine article. The sale of skimmed milk for whole milk, and of spent tea leaves for genuine leaves are illustrations of this kind of fraud. Perhaps the best method of illustrating these various kinds of fraud and adulteration will be to call attention to some of the articles sophisticated in the ways described. No attempt, however, will be made to give a complete list of adulterated articles, for such a list would fill a volume. Attention, therefore, will be called only to the more important articles of food, and to those which are most commonly adulterated. In addition to this, examples will be given of some peculiar forms of adulteration which are little known to the public.

Milk.—Normal cow's milk should contain about three and one-half per cent. of butter fat, and should yield, on standing in a cool place for twenty-four hours, from ten to twenty per cent. by volume of cream. Until the establishment of milk inspection in cities, whole milk was something of a rarity. With careful inspection, such as obtains in Boston, the percentage of adulteration has been largely reduced.

An ingenious method of milk adulteration is sometimes practised by the shrewd husbandman in such a way as to preserve his tender conscience from being seared. The cream in the cow's udder is naturally separated in part from the milk, unless the cow, just previous to milking, be subjected to violent exercise. The first milking, therefore, is less rich in butter fat, and it can be sent directly to the consumer. The last of the milking, called strippings, on the other hand, is nearly pure cream, and can be preserved

for butter-making. Butter fat, being lighter than whole milk, cannot be removed without increasing the density of the remainder above the normal. This density, however, can be reduced to the proper limit by the judicious addition of water. The testing of milk by the lactometer alone is therefore not a certain method of discriminating between a pure and an adulterated article.

Condensed milk is made by evaporating whole milk at a low temperature and in a high vacuum, in copper vessels, yet even at this low temperature some of the distinctive aroma of the milk is carried off by the escaping vapors. It therefore happens that even when evaporated milk is diluted to its original volume with water, it is never exactly itself again. Yet a pure condensed milk is not an adulterated article, for it is sold as condensed milk, and hence no fraud is practiced. When, on the contrary, as is often the case, sugar or salicylic acid is added in order more securely to preserve the condensed product, then a perfect case of adulteration is established. The manufacturer, however, may relieve himself of all responsibility, in so far as the addition of sugar is concerned, by stating on the label the amount added. In cases of deleterious preservatives, however, there would be no excuse. Their use in all cases should be prohibited.

Butter.—In regard to butter, the character of adulteration is well known. The use of oleomargarine as a butter substitute has been practiced for many years. The oleomargarine law, which imposes a tax of two cents a pound on the manufactured product, has not helped to restrict its use, but has rather increased it by giving to the consumer a guarantee of purity. The amount of tax collected on manufactured oleomargarine for the fiscal year ending June 30, 1892, was $945,675, which shows that there were 47,283,750 pounds of oleomargarine manufactured in the United States in twelve months.

The number of retail dealers in oleomargarine increased during the year more than twenty-five per cent. over the preceding year. The amount of tax paid by retail dealers for the fiscal year ending June 30, 1891, was $146,293.70, and for the fiscal year ending June 30, 1892, $204,215.

The increase in the number of wholesale dealers was nearly 100 per cent. The amount of tax paid by wholesale dealers for the fiscal year ending June 30, 1891, was $53,191, and for the fiscal year ending June 30, 1892, $106,036.

There can be no reasonable objection to the use of oleomargarine; it is clean, wholesome and digestible. When it is to be kept for a long time before use, as on ship board or in distant mining camps, it is preferable to butter, because it has but little tendency to become rancid.

Lard.—For similar reasons there can be no possible objection to the use of cotton-seed oil as a substitute for lard or when mixed with lard, provided it be sold for what it is. Most of you are familiar with the great fight which was made against the use of the term "pure refined lard," which was the trade name of a mixture of lard stearine with cotton-seed oil. "Pure refined lard," it was claimed, was a term which had been used so long to designate the mixed product that it had become in reality a trade-mark, and was therefore entitled to respect and protection. In the investigation which was held before the Congressional committees, it appeared that as to the trade the contention was quite justifiable. Goods sold under that name were understood to be mixed. When, however, the mixed product was offered to the consumer, it was purchased with the idea which the name naturally implied, that an extra fine quality of hog's lard was secured.

All attempts to pass a pure lard bill, modelled on the Oleomargarine Act, have heretofore failed in Congress, but several of the States have prohibited the sale of mixed lard, except when offered under the proper name. Manufacturers have, therefore, been gradually forced to abandon the term "refined lard" when applied to this commodity.

I am of the opinion that many persons would prefer a cooking fat largely of vegetable origin to a pure animal product. To me it seems that some State Legislatures have taken a reprehensible course in prohibiting the sale of vegetable oils as a substitute for lard for cooking. The grower of hogs undoubtedly has a right to contend against the sale of vegetable oils as hog fat, but when he

pushes his claim still further and demands that the markets be closed to products as pure and nutritious as his own, he passes beyond the bounds of public support. Every person in the United States who prefers cotton oil to lard should be allowed to purchase his supplies without let or hindrance. Every grower and maker of pure lard has the right to an equally open market, from which every adulterated and mixed lard, offered as pure, should be rigidly excluded.

For a time, a few years ago, when a popular fad prevailed in favor of nitrogenous foods, the true value of fats to the digestive and nutritive economy was not well appreciated. At the present day this is all changed, and we know how to value a fat properly.

It is therefore a matter of no mean importance to protect the public in the use of olive oil instead of cotton oil, of cotton oil instead of lard, and lard instead of a mixture of beef and cotton oil stearine. It is true that cotton oil, when carefully refined, is almost as good a salad dressing as olive oil, but it is very much cheaper, and those who prefer to pay the high price should be secured against fraud. In respect of wholesomeness and digestibility it would be hard to choose wisely between the two.

One of the great difficulties in securing the enactment of a National Pure Food Bill has been the feeling in cotton-growing regions that such a bill would restrict the market for cotton oil. This is true if the fraudulent market is meant. By that I mean the surreptitious sale of cotton oil as olive oil and as lard. But such a bill would not interfere in the least with the legitimate market for this product. Cotton oil, as a food, has such merit of its own as to warrant the belief that it does not require any smuggling to secure for it a wide and rapidly increasing use. The South as well as the North would be the gainer from honest markets for honest foods, and it is a short-sighted policy that leads to a crusade against such legislation as will secure the desired result. It would be a rather unfortunate thing for the whole country should an irrepressible conflict between the *sus* and the *gossipyum* keep our interstate market forever open to mixed or doubtful fats.

Sugar.—The common idea that the grocer puts sand in his sugar is not borne out by the facts in this country. I doubt whether a single pound of white sand has been put into the sugar supply of this country in the last ten years. It is one of those popular fallacies which gain credence inversely proportional to their truth. The granulated and white lump sugars which are found in our markets are almost absolutely pure; as pure indeed as the utmost care in manufacture can make them. Occasionally a little flour or starch may find its way into the powdered sugar, but such instances must be exceedingly rare. Low-grade sugars contain molasses and water as a result of the way in which they are made and dried. In the refineries, after the pure white sugar has been secured, the molasses therefrom is reboiled and a second crop of sugar crystals obtained. These form the so-called coffee sugars of commerce. In a like manner a third crop of rather light colored crystals may often be formed. By a combination of low temperature and high vacuum in boiling, and by a manipulation producing small crystals, a sugar can be made very soft, and, so prepared, it absorbs a good deal of the mother liquor in which its crystals grow. It is possible, in this way, to put on the market a fairly light-colored and attractive sugar, which may not contain more than eighty-five per cent. of pure sugar. This process of making low-grade sugars is practiced chiefly with the product of the sugar cane. In sugar from beets the molasses and mother liquors are usually so highly charged with alkaline salts as to render the manufacture of low-grade sugars, fit for table use, a very difficult matter. In this country, as is well known, the greater part of the sugar consumed is made from sugar cane. Of the 4,000,000,000 pounds which we have eaten in the last twelve months, probably 3,500,000,000 have been grown under tropical suns. The proportion of yellow, coffee and low-grade sugars offered is therefore, greater in our markets than in Europe, where the sugar beet supplies nearly all of the sugar consumed.

Syrups.—In respect of molasses and syrups the bill of health is not quite so clean. The quantity of pure maple syrup

sold annually is well calculated to make the maple forests of Vermont prick up their ears. A very little maple molasses mapleizes the whole jugful; a fact that makers and sellers have not been slow to learn. An extract of hickory bark imparts a misleading flavor to a syrup made from cane sugar and starch, and a patent has been granted by the United States protecting the discoverer of this process in the exercise of his invention. Judicious mixtures of glucose, sugar, syrup and maple flavor are the secrets of the marvellous expansiveness of maple molasses between the tree and the gullet.

"Golden drips," "honey syrups," etc., are names given to compounds made of refinery refuse, glucose and centrifugal cane molasses. The great base of all our table syrups is glucose made from corn starch. I am far from denouncing glucose as a dangerous ingredient in such mixtures. On the contrary, when glucose is properly made, it is both palatable and wholesome, but its sale as maple molasses or as refiner's syrup or as open kettle molasses is clearly fraudulent.

Honey.—Liquid honey is very largely adulterated with glucose. Of 500 samples of honey bought in fifteen large cities and examined by the Chemical Division of the United States Department of Agriculture, nearly forty-five per cent. were found to be fraudulent. Of comb honey, only that is adulterated which comes in bottles or jars. A few years ago, there was a popular impression, which I shared, to the effect that comb honey in the frame was adulterated, but no sample of this kind has ever come under my observation, and I am convinced that such a species of adulteration does not exist. Perhaps there is no class of food producers in the country whose business has been so seriously injured by adulteration as the bee growers. Many of them, however, do not seem to realize the magnitude of the frauds which are perpetrated against them. They have often been known to denounce, as attempts to injure their business, the statements that such frauds are practiced. Of late, since indubitable evidence of fraud has been presented to them, they have determined to use every means to end it.

Coffee.—Almost equally subject to adulteration is ground coffee. The high price of coffee is a special incentive to sophistication. In former days it was largely the custom to buy the green berry, and each consumer would do his own roasting. Now it is fashionable not only to buy the roasted berry but also to buy it in a ground state. Chicory, roasted peas, beans, etc., are often found in large proportions in such preparations, and in fact it is somewhat rare to find a pure ground coffee. It might be held that such sophistication would end with the ground article, but such is not the case. The berries themselves have been imitated both in the green and in the roasted state. The moistened mass of chicory, starch, pea meal, caramel, molasses, etc., is moulded into the proper shape, and, when dried, these imitations might easily escape detection when mixed with the genuine berries. Those who are so fortunately situated as to be permitted to live at home and regale themselves each morning with an aromatic cup of Mocha or Java, scarcely realize what it means to drink a lukewarm concoction of chicory and pea meal, bluish black in color, but decidedly yellow in flavor.

Tea.—Thanks to our customs laws very little tea is found in this country adulterated with foreign leaves. The chief adulterations practised with tea are found in the use of spent leaves and in the practice of facing. The practice of facing consists in treating the leaves with some preparation designed either to increase their weight or to improve their appearance. Salts of iron and copper are often used for this purpose. Some of these facing materials are quite prejudicial to health, and such teas are best excluded from the breakfast table.

Cocoa.—Cocoa and chocolate are largely adulterated with starch and sugar, harmless in themselves, but far cheaper than the meat of the *cocoa theobroma*. The natural oil of the cocoa bean is also often extracted, and its place supplied by a cheaper fat or left without an oil. These various preparations are offered under fancy names and with wonderful claims of excellence. But in general we may say that the

food value of a preparation is not much improved by having it digested before it is eaten. Yet often we see it claimed for a given mixture that it has had all of its difficultly digested components removed and that these are replaced by others with which the gastric juice can have a veritable pic-nic. The digestible cocoas often belong to this class, and, perchance, may have little of the virtues of the original beans left in them.

Canned Foods.—Of canned foods I should like to say something, but it is difficult to select the little which can yet be said. First of all, the material of which the cans are composed is a matter to deserve attention. It is undoubtedly true that glass is the ideal substance for cans designed to preserve food products. But the first cost of these packages and the danger of breakage during filling and transportation, exclude them from competition with tin in all except the choicest brands of preserved foods. Fortunately, tin is a metal which is not only troublesome to the tariff but also resistent to most organic acids. It is acted on very slowly or not at all by most organic acids found in fruits, vegetables and meats. In some countries, such as Germany, the tin which is used in contact with canned foods is required to be almost pure, and to contain not more than one or two per cent. of lead. The most abundant adulterant of tin, as found in tin cans, is lead, and it is against the presence of lead that it is especially necessary to guard, inasmuch as the organic salts of lead, without exception, are poisonous. In this country of personal liberty there is no restriction as to the percentage of lead which tins used for canned foods may contain. We have found as high as twelve per cent. of lead in tin from cans which have contained food designed for consumption. Such a high percentage of this dangerous metal cannot fail to excite alarm. We have also found numerous evidences of erosion on the tinned surfaces exposed to the action of the contents of the can. The contact of the preserved goods with solder should also be carefully prevented, inasmuch as solder contains often as much as fifty per cent. of lead. It is very common, however, to

find lumps of solder in the canned goods and also to find the solder protruding through the points of union of the can and cover so as to be exposed to the action of the contents.

Copper in Peas.—Equally objectionable is the habit of using copper salts to impart a bright green color to canned peas and other goods. The imported French peas are uniformly colored with copper. The addition of a little copper, in any vegetable which it is desired to keep green when served, has a happy effect in that direction, and fashionable cooks have not been slow to learn this. It is true that the quantity of copper which one would eat in a single meal where French peas are served, would not prove greatly injurious, but on that large part of our population who are compelled to dine every day on truffles and peas interspersed with terrapin and champagne, there is great danger of the copper acting with accumulative effect.

I have already spoken of the danger which may lurk in preservatives, such as salicylic acid, but there is also an occasional source of danger in the development of nitrogenous bodies called ptomaines in preserved meats. These bodies may develop with astounding rapidity if a can of meat be opened, and not eaten for a day or two. An illustration of the fatality of the action of such bodies is unfortunately often found in the case of tyroxicon, a poison often developed in milk or cream.

The above will serve as illustrations of the more common forms of adulteration to which our foods are subjected. The idea might be formed from this array of facts that foods are almost all adulterated, and that it is extremely difficult to obtain anything pure. Newspapers love to magnify these accounts of adulteration. What I have placed before you has not been for the purpose of exciting a panic on the subject of foods. Much the greater part of foods which Americans eat is pure and wholesome. It is only the small quantity of adulterated food from which we should strive to protect ourselves. This exaggeration of the adulteration of food has been humorously portrayed by Burdette in a little scrap of rhyme, entitled

A VICTIM OF DELUSION.

Placid I am, content, serene.
I take my slab of gypsum bread,
And chunks of oleomargarine
Upon its tasteless sides I spread.

The egg I eat was never laid
By any cackling, feathered hen;
But from the Lord knows what 'tis made
In Newark by unfeathered men.

I wash my simple breakfast down
With fragrant chickory so cheap;
Or with the best black tea in town—
Dried willow leaves—I calmly sleep.

But if from man's vile arts I flee
And drink pure water from the pump,
I gulp down infusoriæ,
And hideous rotatoriæ,
And wriggling polygastricæ,
And slimy diatomaceæ,
And hard-shelled orphryocercinæ,
And double-barrelled kolpodæ,
Non-loricated ambrœilæ,
And various animalculæ,
Of middle, high and low degree;
For nature just beats all creation
In multiplied adulteration.

Even the conservative work of the Department of Agriculture in investigations of food adulteration, which I have had the honor to conduct during the past six years, becomes most highly sensational material when portrayed in the columns of the daily journal. In the *Philadelphia Star*, of recent date, appeared the following remarkable statement of the work of the Chemical Division:

"Glucose, it appears, is the greatest of all adulterants. It is used for making cheap candy, sugars, jellies and syrups. Apple sauce is pumpkin boiled in cider. It is said that the cheap confectionery and liquors are the articles most injuriously adulterated. Candy commonly contains much fusel oil and other poisons. Strawberry ice cream—a plate of it—often contains almost more fusel oil than five glasses of poor whiskey. It is colored with red aniline dye.

Licorice drops are usually made out of candy factory sweepings. Wine is frequently nothing but water with a percentage of crude alcohol from grain or the refuse of beet refineries, colored with burnt sugar, flavored with oil of cognac and given an agreeable woody taste with a little catechu. When one buys tea for $1 a pound, one is very likely to pay in reality $2 a pound because one-half the quantity is currant leaves. Grated horseradish is sometimes composed of turnip. Flour is frequently weighted with soapstone. Sweetened water, sharpened with citric and tartaric acids and flavored with the oil of orange skin, makes orange cider. Real honey can be distinguished, under the microscope, by the pollen grains it contains. They have wonderfully beautiful forms and the very flowers from which the honey was obtained can be identified by the various exquisite shapes of these fructifying germs."

The above startling facts in regard to adulteration, which are attributed to the Department of Agriculture, are worthy of especial notice because not one of them was ever abstracted from any report of the Department. Scarcely a single instance of the adulterations mentioned above has ever been observed and reported on by the chemists of the Department. Thus it is seen that the popular idea of adulteration is really very much at fault and this has been due largely to the exaggerated statements of presumably honest men who desire to call attention to the fraud and to prevent it by exciting the popular mind against it. The adulteration of our foods and drugs is certainly bad enough, but in my mind it does no good whatever to exaggerate, falsify and misstate the results of careful and unbiased investigations. As has before been intimated, in this address, the remedy against all these things lies clearly in the power of the people. Wise laws wisely administered, a careful system of inspection, a demand for pure food, will secure the people in their right. It is not the rich for whom we should work, but the poor, and they should be protected against frauds in food; frauds not so dangerous on account of being deleterious to health as because of their pretensions to furnish to the poorer part of our people a food

ostensibly pure and nutritious but in reality valueless. It is not supposed for a moment that any system of legislation can entirely prevent the perpetration of frauds upon the community, but at least these crimes can be made punishable and their perpetrators may be compelled to endure the penalty of their misdeeds.

NOTES ON THE DESIGN OF GEAR WHEELS.*

By Prof. L. F. Rondinella.

Toothed or gear wheels are used in machinery to transmit power from one shaft to another near it. The most important classes are: (*a*) spur wheels, (*b*) bevel wheels, (*c*) worm wheels, (*d*) lantern wheels, (*e*) Crown wheels and (*f*) cog wheels.

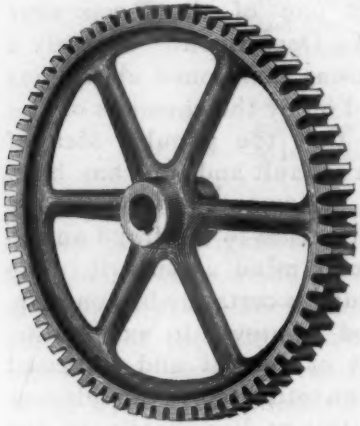


Fig. 1.

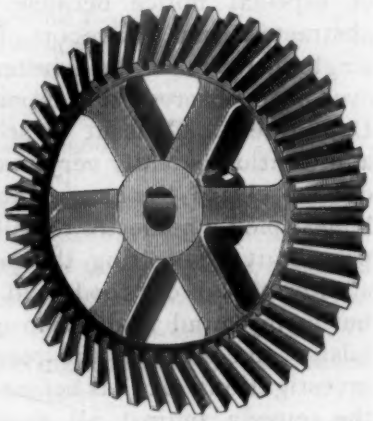


Fig. 2.

(*a*) A *spur wheel* (*Fig. 1*) is one in which the teeth extend radially outward from the rim, in the plane of the wheel. Two spur wheels are used to transmit power between parallel shafts.

* Revised and augmented from lecture notes prepared originally for students of the Philadelphia Manual Training School.

(*b*) A *bevel wheel* (*Fig. 2*) is one in which the teeth extend outward perpendicularly from a rim making an oblique angle with the plane of the wheel, like the frustum of a cone. Two bevel wheels are used to transmit power between non-parallel shafts.

Mitre wheels (*Fig. 3*) are bevel wheels in which the teeth are at 45° to the face of the wheel and are used to transmit power between *perpendicular* shafts.

(*c*) A *worm wheel* (*Fig. 4*) has its teeth cut slantingly across the rim of the wheel, to gear with an endless screw or *worm*. This combination is used to transmit power between shafts

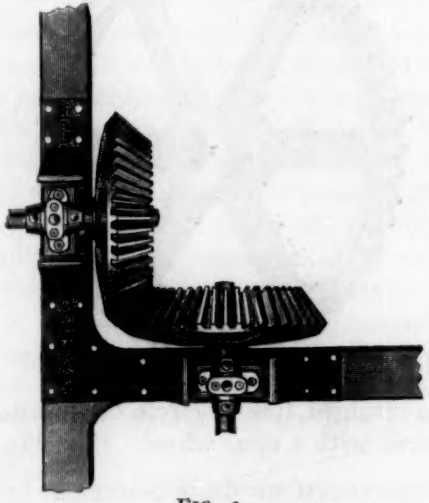


FIG 3.

running at very different speeds, and with their axes in different planes.

(*d*) A *lantern wheel* is one in which the teeth consist of rods connecting two circular discs or faces. It is most used in clock-work, geared with an ordinary spur wheel.

(*e*) A *crown wheel* is one in which the teeth extend at right angles from the side or face of the wheel, and is used in rough gearing between perpendicular shafts.

(*f*) A *cog wheel* is any kind of gear wheel in which the teeth are made separate (generally of wood), and inserted in mortises in the rim of the wheel.

An *internal gear* or *annular wheel* is one in which the teeth are on the *inside* instead of on the outside of the rim.

In a pair of gear wheels, the wheel which imparts the power is called the *driver;* that to which power is imparted is called the *driven wheel* or *follower.* A small gear wheel is called a *pinion.* A *rack* is a straight bar with teeth extending outward perpendicularly from its edge. It moves,

FIG. 4.

therefore, in a straight line (a circle of infinite radius), and is usually geared with a spur wheel. (See *Fig. 5* or *6.*)

TEETH OF GEAR WHEELS.

The circle in gear wheels which corresponds to the circumference of solids of revolution rolling one upon another is called the *pitch circle.* This is the line of reference in designing all toothed gears, its diameter being used to designate the size of the wheel, and the proportions for the teeth and spaces being laid off upon or at right angles to it. Good proportions for the teeth of *cast-iron gears* are as follows (*Figs. 5* and *6*):

$a\ b$ = part of the pitch circle.
$c\ e$ = circular pitch = p.
$c\ d$ = thickness of tooth = $\frac{15}{32}\ p$ or 0·47 p.

$d\,e$ = width of space = $\frac{17}{32}\,p$ or 0·53 p.
f = height of face (above pitch circle) = $\frac{11}{32}\,p$ or 0·34 p.
g = depth of flank (below pitch circle) = $\frac{13}{32}\,p$ or 0·41 p.
$g + f$ = total height of tooth = $\frac{3}{4}\,p$ or 0·75 p.
$g - f$ = clearance = $\frac{1}{16}\,p$ or 0·07 p.
Thickness of rim = 0·50 p.
Perpendicular breadth of face = 2·50 p.
Other proportions as in belt pulleys.

In dimensioning bevel gears the sizes should always refer to the larger face.

CIRCULAR AND DIAMETRAL PITCH.

These different proportions of the tooth are all expressed above in terms of the absolute or *Circular Pitch*, which is *the distance on the pitch line between corresponding points of consecutive teeth.* This absolute pitch is technically called *circular* pitch to distinguish it from the relative or *Diametral Pitch* by which the number of teeth is expressed in terms of the pitch diameter; as, *e. g.*, a diametral pitch of "$\frac{1}{10}$ inch" or "10 per inch," or simply "10 pitch" means that for each inch in the diameter of the pitch circle there are ten teeth on the circumference of the wheel. The great convenience of this system lies in the fact that the number of teeth can be found at once if the diameter is given—or the diameter can be found if the number of teeth is given—from the equation,

$$\textit{No. of teeth} = \textit{Diametral pitch} \times \textit{diameter},$$

the diametral pitch being taken as expressed in the last two forms above.

The circular pitch may be found as the circumference of a circle is found from its diameter, *i. e.*, by multiplying the diametral pitch in inches by 3·1416.

TOOTH CURVES.

The curves used in shaping the teeth of gear wheels are the *cycloid*, *epicycloid* and *hypocycloid*, and the *involute*.

A *Cycloid* is the curve generated by a point in the circumference of a circle rolling along a straight line. It is used for the faces and flanks of teeth in a rack.

An *Epicycloid* is the curve generated by a point in the circumference of a circle rolling on the *outside* of another circle. It is used for the faces of teeth in a wheel.

An *Hypocycloid* is the curve generated by a point in the circumference of a circle rolling on the *inside* of another circle. It is used for the flanks of teeth in a wheel.

To form the curves for cycloidal teeth the circumference of the describing circle to roll on the pitch line should be equal to 6 p; or its diameter should equal

$$\frac{6\,p}{3{\cdot}1416} = 1{\cdot}9\,p.$$

When the circumference of the pitch circle = 12 p., viz: in a wheel with 12 teeth, the hypocycloids for the flanks of the teeth will become straight, radial lines.

An *Involute* is the curve generated by a point in a straight line moving tangentially around a circle, *e. g.*, the end of a cord held taut and wound around a cylinder. It is used with a radial line in forming the profiles of teeth in a wheel.

PROPORTIONING GEAR TRAINS.

A *train* of gearing consists of two or more gear wheels meshing together, usually to change the speed at which power is transmitted from one shaft to another. The speed (number of revolutions per minute) of the wheels varies inversely as their pitch diameters, their circumferences, or their numbers of teeth—the latter being necessarily of the same pitch in both wheels. These values can be calculated from one another by substitution in the proper members of the following equation:

$$\frac{\text{Speed of Driver } (d)}{\text{Speed of Follower } (f)} = \frac{\text{Pitch Diam. of } f}{\text{Pitch Diam. of } d} =$$

$$= \frac{\text{Circum. of } f}{\text{Circum. of } d} = \frac{p}{p} \times \frac{\text{no. of teeth in } f}{\text{no. of teeth in } d}$$

The *distance between shaft centres* equals half the sum of the two pitch diameters.

The number of cycloidal teeth in the pinion or smaller wheel should not be less than twelve, and with involute

teeth it should not be less than sixteen. Circular pitch for cast gears should be limited between one-half and five inches.

In a wheel of good cast iron, where the breadth of face equals 2·5 p, the number of teeth (t) necessary to safely transmit any horse-power (P) at a given number of revolutions per minute (r) may be found from the equation

$$t = 800 \frac{P}{p^3 r}$$

ODONTOGRAPH TABLES FOR CAST GEARS.

TO DRAW CYCLOIDAL TEETH.

Table 1.—Find the given *number of teeth* for the wheel in either outside column, and opposite, in the column headed

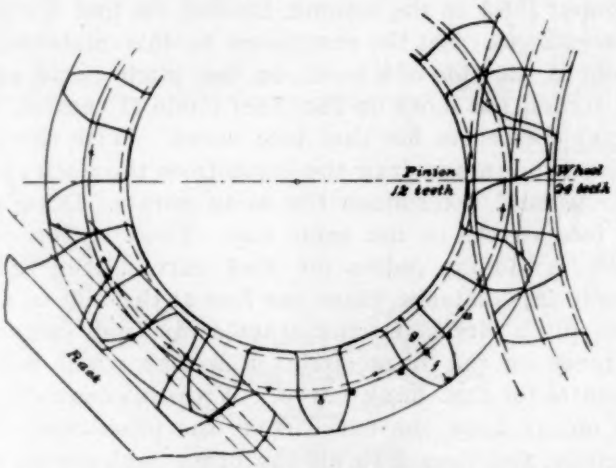


FIG. 5—Cycloidal teeth.

by the given circular pitch, find the diameter of the pitch circle. Lay this off on a centre line, and through its extremities, from the centre point draw the pitch circle. Divide it into as many equal spaces as there are to be teeth in the wheel, and the length of each *arc* should exactly equal the given circular pitch. (The length of the chord is of course less). At the bottom of the same column in the table, find the *thickness* of the tooth, and lay it off around the

pitch circle on the same side of each pitch point. The part of the pitch remaining will be the proper width of space. In the same column of the table find the *height of face* and *depth of flank*, and lay them off on the centre line, the former outside and the latter inside of the pitch circle. Through these two points, from the wheel centre, draw circles which will determine the points and roots of all the teeth. Then in

Table 2,—find the given number of *teeth* in either outside column, and opposite, under the proper *pitch*, in the column headed *Fa.* find the radius of the circle for centres of *face* curves, and in the column *Fl.* the radius of the circle for centres of *flank* curves. With these radii draw those circles from the wheel centre. (There is no *Fl.* radius for twelve teeth, as the flanks are straight, radial lines.) Then in

Table 3,—opposite the proper number of *Teeth*, and under the proper *Pitch* in the column headed *Fa.* find the radius for *face* curves. Set the compasses to this distance, place one foot at the side of a tooth on the pitch circle and the other across that tooth on the inner circle of centres, which will give the centre for that face curve. With this centre and the same radius draw the curve from the pitch circle to the circle that determines the tooth points. Draw all the other face curves in the same way. Then in the column headed *Fl.* find the radius for *flank* curves. Set the compasses to this distance, place one foot at the side of a tooth on the pitch circle, and the other away from (not across) that tooth on the outer circle of centres, which will give the centre for that flank curve. With this centre and the same radius draw the curve from the pitch circle to the root circle, and then draw all the other flank curves in the same way. Fillet the corners to a radius equal to the *clearance* obtained from *Table 1*.

In drawing a rack, the pitch line, the limiting lines for the teeth, and the lines of centres are all straight; the height of face and the *plus* distance for the line of flank centres are measured outward from the pitch line, and the depth of flank and the *minus* distance for the line of face centres are measured inward from it. The centres are then laid off, and the curves drawn as in a wheel.

TO DRAW INVOLUTE TEETH.

Draw the pitch circle; lay off on it the widths of teeth and spaces, and draw the limiting circles for points and roots as described for cycloidal teeth in first paragraph above. Then in

Table 4,—find the given number of *teeth* in either outside column, and opposite, under the proper *Pitch*, in the column headed *Cen.*, find the radius for the circle of centres, and

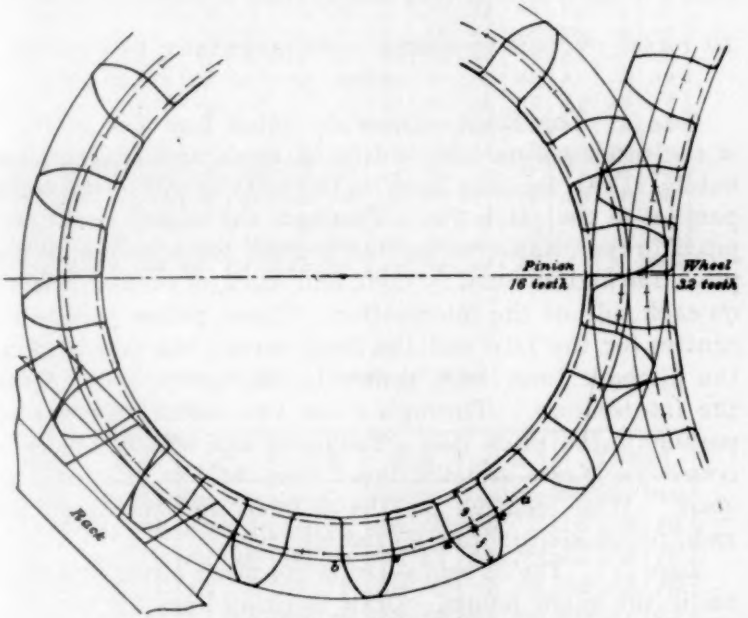


FIG. 6—Involute teeth.

then draw that circle concentric with the pitch circle. In the column headed *Cur.* find the radius for the tooth curves. Set the compasses to this distance, place one foot at the side of a tooth on the pitch circle and the other across that tooth on the circle of centres, which will give the centre for that face curve. With this centre and the same radius draw the curve from the circle of centres to the limiting circle for tooth points. Draw all the other tooth curves in the same way, and finish the flanks by straight, radial lines with the

corners filleted to a radius equal to the *clearance* obtained from *Table 1*.

In the rack to gear with involute teeth the sides of its teeth are straight lines drawn at 75° to the pitch line as described under involute teeth. See *Case I*, below.

The values in the tables are obtained by the methods of using circular arcs for cycloidal and involute tooth-profiles, as described below. These are modifications by the writer of the constructions of Willis and Reuleaux, and will be found to approximate very closely indeed to the true curves.

TO DRAW CYCLOIDAL TEETH APPROXIMATELY BY CIRCULAR ARCS.

Case I : The Rack.—Draw the pitch line and mark on it the pitch points—the widths of teeth and spaces alternately. Draw limiting lines for the total height of the teeth, parallel to the pitch line. Through the *middle* point of a pitch, draw a line crossing the nearest tooth *outside* of the pitch line and inclined 15° to it, and mark off on that line ·5 p on each side of the intersection. Those points will be the centres for the face and the flank curves, the radius being the distance from each centre to the pitch point *beyond* the intersection. Through these two centres draw lines parallel to the pitch line. The outer line will be *the line of centres for flanks* and the inner one *the line of centres for faces.* With centres on these lines, and the respective radii found above, draw all tooth curves.

Case II : The Wheel.—Draw the pitch circle and mark on it the pitch points. Draw limiting lines for the total height of the teeth, concentric with the pitch circle. Through the *middle* point of a pitch draw a radius and also a line inclined 75° to it, crossing the nearest tooth *outside* the pitch line and a line perpendicular to this or inclined 15° to the radius. Mark points on the last line 1·84 p (approximately $1\frac{7}{8}$ p) on both sides of the intersection, and through those points and the wheel centre draw straight lines until they cross the 75° line. The points thus found on the 75° line will be the centres, and the distances from them to the pitch points beyond the intersec-

TABLE I.—DIAMETERS OF PITCH CIRCLES AND PROPORTIONS OF TEETH.

No. of Teeth	Pitch in Inches. ½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3	No. of Teeth
12	1 11/16	2 7/16	3 3/16	4 1/16	5 1/16	6 1/16	7 1/16	8 1/16	9 1/16	10 1/16	11 1/16	12
13	2 1/16	3 1/16	4 1/16	5 1/16	6 1/16	7 1/16	8 1/16	9 1/16	10 1/16	11 1/16	12 1/16	13
14	2 1/16	3 1/16	4 1/16	5 1/16	6 1/16	7 1/16	8 1/16	10	11 1/16	12 1/16	13 1/16	14
15	2 1/16	3 1/16	4 1/16	6	7 1/16	8 1/16	9 1/16	10 1/16	11 1/16	13 1/16	14 1/16	15
16	2 1/16	3 1/16	5 1/16	6 1/16	7 1/16	8 1/16	10 1/16	11 1/16	12 1/16	14	15 1/16	16
17	2 1/16	4 1/16	5 1/16	6 1/16	8 1/16	9 1/16	10 1/16	12 1/16	13 1/16	14 1/16	16 1/16	17
18	2 1/16	4 1/16	5 1/16	7 1/16	8 1/16	10	11 1/16	12 1/16	14 1/16	15 1/16	17 1/16	18
19	3	4 1/16	6 1/16	7 1/16	9 1/16	10 1/16	12 1/16	13 1/16	15 1/16	16 1/16	18 1/16	19
20	3 1/16	4 1/16	6 1/16	8	9 1/16	11 1/16	12 1/16	14 1/16	15 1/16	17 1/16	19 1/16	20
22	3 1/16	5 1/16	7	8 1/16	10 1/16	12 1/16	14	15 1/16	17 1/16	19 1/16	21 1/16	22
24	3 1/16	5 1/16	7 1/16	9 1/16	11 1/16	13 1/16	15 1/16	17 1/16	19 1/16	21	22 1/16	24
26	4 1/16	6 1/16	8 1/16	10 1/16	12 1/16	14 1/16	16 1/16	18 1/16	20 1/16	22 1/16	24 1/16	26
28	4 1/16	6 1/16	8 1/16	11 1/16	13 1/16	15 1/16	17 1/16	20 1/16	22 1/16	24 1/16	26 1/16	28
30	4 1/16	7 1/16	9 1/16	11 1/16	14 1/16	16 1/16	19 1/16	21 1/16	23 1/16	26 1/16	28 1/16	30
40	6 1/16	9 1/16	12 1/16	15 1/16	19 1/16	22 1/16	25 1/16	28 1/16	31 1/16	35	38 1/16	40
60	9 1/16	14 1/16	19 1/16	23 1/16	28 1/16	33 1/16	38 1/16	43	47 1/16	52 1/16	57 1/16	60
80	12 1/16	19 1/16	25 1/16	31 1/16	38 1/16	44 1/16	50 1/16	57 1/16	63 1/16	70	76 1/16	80
100	15 1/16	23 1/16	31 1/16	39 1/16	47 1/16	55 1/16	63 1/16	71 1/16	79 1/16	87 1/16	95 1/16	100
Thickness	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	Thickness
Height of Face	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	Height of Face
Depth of Flank	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	Depth of Flank
Clearance	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	Clearance
Pitch	½"	¾"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	Pitch

TABLE II.—RADII OF CIRCLES FOR CENTRES.

Pitch →	½"		¾"		1"		1¼"		1½"		1¾"		2"		2¼"		2½"		2¾"		3"		← Pitch
Teeth	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Teeth
12	1/16	—	1/16	—	1 1/16	—	2 1/16	—	2 1/16	—	3 1/16	—	3 1/16	—	4 1/16	—	4 1/16	—	5 1/16	—	5 1/16	—	12
13	1	3/16	1 1/16	5/16	2	7/16	2 1/16	9/16	3	10/16	3 1/16	12/16	4 1/16	14/16	4 1/16	16/16	5 1/16	18/16	5 1/16	19/16	6 1/16	21/16	13
14	1 1/16	2/16	1/16	3/16	2 1/16	4/16	2 1/16	5/16	3 1/16	6/16	3 1/16	7/16	4/16	9	4 1/16	10/16	5 1/16	11/16	6	12/16	6 1/16	13/16	14
15	1 1/16	1 1/16	1/16	2/16	2 1/16	3 1/16	2 1/16	4 1/16	3 1/16	5/16	4 1/16	6/16	4 1/16	7/16	5/16	8 1/16	5/16	9/16	6 1/16	10/16	7 1/16	11/16	15
16	1/16	1 1/16	1/16	2/16	2/16	3 1/16	3/16	4/16	3/16	5 1/16	4/16	6/16	4 1/16	7/16	5 1/16	8/16	6/16	9	6 1/16	9 1/16	7 1/16	10 1/16	16
17	1/16	1/16	1/16	2/16	2/16	3/16	3/16	4/16	3 1/16	5/16	4/16	6/16	5/16	7	5/16	7/16	6 1/16	8/16	7/16	9/16	7 1/16	10/16	17
18	1 1/16	1/16	2/16	2/16	2 1/16	3 1/16	3/16	4 1/16	4/16	5/16	4 1/16	6/16	5 1/16	7/16	6/16	7 1/16	7	8 1/16	7 1/16	9 1/16	8 1/16	10 1/16	18
19	1/16	1 1/16	2/16	2 1/16	2 1/16	3/16	3 1/16	4 1/16	4/16	5/16	5/16	6 1/16	5/16	7/16	6 1/16	8/16	7/16	9/16	8/16	9 1/16	8 1/16	10/16	19
20	1/16	1 1/16	2 1/16	2/16	3/16	3 1/16	3 1/16	4/16	4/16	5/16	5 1/16	6/16	6/16	7/16	7/16	8/16	7 1/16	9/16	8 1/16	10/16	9/16	11/16	20
22	1 1/16	1/16	2/16	2 1/16	3/16	3 1/16	4/16	4 1/16	5/16	5/16	6	6 1/16	6/16	7 1/16	7/16	8 1/16	8 1/16	9 1/16	9/16	10/16	10/16	11 1/16	22
24	1/16	2/16	2 1/16	3/16	3/16	4/16	4/16	5/16	5/16	6 1/16	6/16	7/16	7/16	8/16	8/16	9/16	9/16	10 1/16	10/16	11/16	11/16	12/16	24
26	2 1/16	2/16	3 1/16	3 1/16	4/16	4 1/16	5/16	5 1/16	6 1/16	6 1/16	7/16	7 1/16	8/16	8 1/16	9/16	10/16	10 1/16	11/16	11/16	12/16	12/16	13 1/16	26
28	2/16	2 1/16	3/16	3/16	4 1/16	4/16	5 1/16	5 1/16	6/16	7/16	7 1/16	8/16	8/16	9/16	9 1/16	10/16	10 1/16	11/16	12/16	13/16	13/16	14/16	28
30	2 1/16	2 1/16	3 1/16	3 1/16	4/16	5/16	5/16	6/16	7/16	7/16	8/16	8/16	9 1/16	10/16	10 1/16	11/16	11/16	12/16	12 1/16	13 1/16	14/16	15/16	30
40	3/16	3/16	4/16	4 1/16	6/16	6 1/16	7 1/16	8/16	9/16	9/16	11	11 1/16	12/16	13/16	14 1/16	14/16	15/16	16/16	17/16	18/16	18 1/16	19 1/16	40
60	4/16	4/16	7/16	7/16	9 1/16	9/16	11 1/16	12/16	14/16	14/16	16/16	17/16	18 1/16	19/16	21/16	21 1/16	23/16	24/16	26/16	26 1/16	28 1/16	29/16	60
80	6/16	6 1/16	9 1/16	10 1/16	12/16	13/16	15 1/16	17 1/16	18 1/16	20 1/16	22/16	24/16	25/16	27/16	28 1/16	31/16	31/16	34 1/16	34 1/16	38/16	37/16	41/16	80
100	7 1/16	8/16	11 1/16	12/16	15/16	16/16	19/16	20/16	23 1/16	24/16	27 1/16	28/16	31/16	32/16	35 1/16	36/16	39/16	40/16	43 1/16	44/16	47/16	48/16	100
Rack	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	−1/16	+1/16	Rack

TAB

Pitch →	½"		¾"		1"		1¼"	
Teeth	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.
12	1/16	—	1/16	—	1/16	—	1/16	—
13	1/16	3 1/16	1/16	5/16	1/16	6/16	1/16	8/16
14	1/16	1/16	1/16	2 1/16	1/16	3/16	1/16	4 1/16
15	1/16	1/16	1/16	2/16	1/16	2/16	1/16	3/16
16	1/16	1/16	1/16	1/16	1/16	2/16	1/16	3/16
17	1/16	1/16	1/16	1/16	1/16	2/16	1/16	2 1/16
18	1/16	1/16	1/16	1/16	1/16	1/16	1/16	2/16
19	1/16	1/16	1/16	1/16	1/16	1/16	1/16	2/16
20	1/16	1/16	1/16	1/16	1/16	1/16	1/16	2/16
22	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
24	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
26	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
28	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
30	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
40	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
60	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
80	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
100	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
Rack	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16

TABLE IV.—RADII FOR CI

Pitch ½"		¾"		1"		1¼"	
Teeth	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.
16	1/16	1/16	1 1/16	1/16	2 1/16	1/16	3 1/16	1/16
17	1/16	1/16	1 1/16	1/16	2 1/16	1/16	3 1/16	1/32
18	1/16	1/16	2/16	1/16	2 1/16	1/16	3 1/16	1/32
19	1/16	1/16	2/16	1/16	2 1/16	1/16	3 1/16	1/32
20	1/16	1/16	2/16	1/16	3/16	1/16	3/16	1/16
22	1/16	1/16	2/16	1/16	3 1/16	1/16	4/16	1/16
24	1/16	1/16	2/16	1/16	3 1/16	1/16	4/16	1/16
26	2/16	1/16	3/16	1/16	4/16	1/16	5/16	1/16
28	2/16	1/16	3/16	1/16	4/16	1/16	5/16	1/16
30	2/16	1/16	3/16	1/16	4/16	1/16	5/16	1/32
40	3/16	1/16	4/16	1/16	6/16	1/16	7/16	2
60	4/16	1/16	6/16	1/16	9/16	2/16	11/16	3
80	6/16	1/16	9/16	2/16	12/16	3/16	15/16	3/16
100	7/16	2	11/16	3	15/16	3/16	19/16	4/16

TABLE III.—RA

Pitch —	½"		¾"		1"		1¼"		1½"	
Tooth	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.
12	1/4	—	3/8	—	1/2	—	5/8	—	1 1/8	—
13	1/4	3 15/16	3/8	5 1/16	1/2	6 1/16	5/8	8 1/16	1 1/8	10 1/8
14	1/4	1 1/16	3/8	2 11/16	1/2	3 1/16	5/8	4 3/16	1 1/8	5 1/8
15	1/4	1 1/16	3/8	2 1/16	1/2	2 1/16	5/8	3 1/16	1 1/8	4 1/16
16	1/4	1 1/16	3/8	1 1/16	1/2	2 1/16	5/8	3 1/16	1 1/8	3 1/16
17	1/4	1 1/16	3/8	1 1/16	1/2	2 1/16	5/8	2 1/16	1 1/8	3 1/16
18	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
19	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
20	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
22	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
24	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
26	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
28	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
30	1/4	1/16	3/8	1 1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
40	1/4	1/16	3/8	1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
60	1/4	1/16	3/8	1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
80	1/4	1/16	3/8	1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
100	1/4	1/16	3/8	1/16	1/2	1 1/16	5/8	2 1/16	1 1/8	2 1/16
Rack	1/4	1/4	3/8	3/8	1/2	1/2	5/8	5/8	1 1/8	1 1/8

TABLE IV.—RADII FOR CIRCLES OF C

In

¾"	3" — Pitch		
Fl.	Fa.	Fl.	Tooth
—	5 11/16	—	12
19 1/16	6 1/16	21 1/4	13
12 3/8	6 7/8	13 1/4	14
10 1/4	7 1/16	11 7/8	15
9 1/16	7 5/16	10 1/16	16
9 1/4	7 11/16	10 1/4	17
9 1/16	8 1/16	10 1/16	18
9 1/16	8 1/16	10 3/8	19
10 1/16	9 1/8	11 1/16	20
10 1/4	10 1/16	11 1/16	22
11 1/4	11 1/4	12 5/8	24
12 5/8	12 5/8	13 15/16	26
13 1/16	13 3/4	14 1/4	28
13 15/16	14 1/16	15 1/16	30
18 3/4	18 15/16	19 15/16	40
26 1/16	28 1/16	29 1/4	60
38 1/16	37 1/8	41 3/8	80
44 1/8	47 1/8	48 1/8	100
+ 1/16	− 3/8	+ 3/8	Rack

Pitch ½"			¾"		1"		1¼"		1½"		
Tooth	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	C
16	1 1/4	7/16	1 13/16	5/32	2 5/16	3/8	3 1/16	1/2	3 13/16	5/8	4
17	1 7/16	11/32	1 11/16	1/4	2 1/16	11/16	3 1/16	27/32	3 15/16	1	4
18	1 11/16	3/8	2 1/16	11/32	2 11/16	23/32	3 11/16	29/32	4 7/16	1 1/16	4
19	1 15/16	1/4	2 7/16	5/16	2 15/16	3/4	3 15/16	1	4 15/16	1 1/4	5
20	1 7/8	15/32	2 7/8	1/2	3 1/16	15/16	3 7/8	1	4 7/8	1 1/4	5
22	1 13/16	7/8	2 3/4	23/32	3 11/16	1	4 1/4	1 3/32	5 5/16	1 5/16	5
24	1 13/16	15/16	2 3/4	23/32	3 13/16	1 1/16	4 5/8	1 5/16	5 3/4	1 7/16	6
26	2	1/4	3	25/32	4	1 5/32	5 1/32	1 3/8	6 1/32	1 3/4	7
28	2 1/16	5/16	3 1/4	27/32	4 1/16	1 1/8	5 1/16	1 3/8	6 1/4	1 11/16	7
30	2 1/16	13/32	3 1/16	29/32	4 1/8	1 1/16	5 1/16	1 3/8	6 1/16	1 11/16	8
40	3 1/16	11/16	4 1/8	1 1/16	6 1/16	1 13/32	7 13/32	2	9 1/32	2 3/8	10
60	4 1/8	1 1/16	6 1/16	1 25/32	9 1/32	2 3/8	11 13/32	3	13 29/32	3 7/16	16
80	6 1/16	1 13/32	9 1/32	2 3/8	12 1/16	3 1/16	15 7/8	3 31/32	18 11/16	4 15/32	2
100	7 13/32	2	11 13/32	3	15 7/8	3 31/32	19 7/8	4 31/32	23 7/16	5 11/16	2

TABLE III.—RADII FOR TOOTH CURVES.

1¼"		1½"		1¾"		2"		2¼"		2½"		2¾"		3" Pitch		
Fl.		Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Fa.	Fl.	Teeth
—	1 1/16	—	—	1 3/16	—	1 5/16	—	1 7/16	—	1 9/16	—	2 1/16	—	2 5/16	—	12
8 1/16	1 1/16	10 1/16	1 1/16	12 1/16	1 1/16	13 7/16	1 1/16	15 1/16	1 1/16	17 1/16	2 1/16	19 1/16	2 1/16	20 9/16	13	
4 3/16	1 1/16	5 1/16	1 1/16	6 1/16	1 1/16	7 1/16	1 1/16	8 1/16	1 1/16	9 1/16	1 1/16	10 1/16	2 1/16	11 5/16	14	
3 1/16	1 1/16	4 1/16	1 1/16	5 1/16	1 1/16	5 7/16	1 1/16	6 1/16	1 1/16	7 1/16	2 1/16	8 1/16	2 1/16	8 9/16	15	
3 1/16	1 1/16	3 11/16	1 1/16	4 1/16	1 1/16	4 7/16	1 1/16	5 1/16	1 1/16	6 1/16	2 1/16	6 11/16	2 1/16	7 5/16	16	
2 15/16	1 1/16	3 1/16	1 1/16	3 11/16	1 1/16	4 1/16	1 1/16	4 11/16	1 1/16	5 1/16	2 1/16	5 11/16	2 1/16	6 1/16	17	
2 15/16	1 1/16	2 15/16	1 1/16	3 1/16	1 1/16	3 7/16	1 1/16	4 1/16	1 1/16	4 11/16	2 1/16	5 1/16	2 1/16	5 9/16	18	
2 1/16	1 1/16	2 13/16	1 1/16	3 1/16	1 1/16	3 7/16	1 1/16	4 1/16	1 1/16	4 11/16	2 1/16	4 15/16	2 1/16	5 5/16	19	
2 1/16	1 1/16	2 13/16	1 1/16	3	1 1/16	3 7/16	1 1/16	3 15/16	2	4 5/16	2 1/16	4 11/16	2 1/16	5 1/16	20	
1 15/16	1 1/16	2 11/16	1 1/16	2 13/16	1 1/16	3 1/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	2 1/16	4 11/16	22	
1 15/16	1 1/16	2 11/16	1 1/16	2 13/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	2 1/16	4 11/16	24	
1 1/16	1 1/16	2 1/16	1 1/16	2 11/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	2 1/16	4 11/16	26	
1 1/16	1 1/16	2	1 1/16	2 11/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	2 1/16	4 11/16	28	
1 1/16	1 1/16	1 15/16	1 1/16	2 11/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	2 1/16	4 11/16	30	
1 1/16	1 1/16	1 15/16	1 1/16	2 1/16	1 1/16	2 1/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	40	
1 1/16	1 1/16	1 15/16	1 1/16	1 15/16	1 1/16	2 1/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	60	
1 1/16	1 1/16	1 1/16	1 1/16	1 15/16	1 1/16	2 1/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	80	
1 1/16	1 1/16	1 1/16	1 1/16	1 15/16	1 1/16	2 1/16	1 1/16	2 15/16	1 1/16	3 7/16	2 1/16	3 15/16	2 1/16	4 5/16	100	
1 1/16	1 1/16	1 1/16	1 1/16	2	2	2 1/16	2 1/16	2 1/16	2 1/16	2 1/16	2 1/16	3	3	Rack		

FOR CIRCLES OF CENTRES AND FOR TOOTH CURVES. (*In Inches.*)

Involute Teeth.

1¼"		1½"		1¾"		2"		2¼"		2½"		2¾"		3" Pitch		
Cur.		Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Cen.	Cur.	Teeth
4/16		3 13/32	4/16	4 3/16	1 3/16	4 11/32	1 3/32	5 5/16	1 7/16	6 3/16	1 11/32	6 31/32	1 3/4	7 11/32	1 29/32	16
3 27/32		3 15/16	1	4 13/32	1 3/16	5 1/4	1 11/32	5 29/32	1 17/32	6 15/32	1 15/16	7 7/32	1 15/32	7 7/8	2 1/32	17
3 29/32		4 3/16	1 1/16	4 27/32	1 1/4	5 5/16	1 7/16	6 1/4	1 3/4	6 15/16	1 25/32	7 5/8	1 31/32	8 11/32	2 5/32	18
4/16		4 13/32	1 1/4	5 1/8	1 5/16	5 3/8	1 1/2	6 13/32	1 11/16	7 11/32	1 7/8	8 1/16	2 1/16	8 31/32	2 1/4	19
1		4 5/8	1 1/16	5 11/32	1 3/8	6 1/16	1 19/32	6 7/8	1 15/16	7 31/32	2	8 1/4	2 1/16	9 3/32	2 3/8	20
1 3/32		5 1/32	1 1/16	5 15/16	1 13/32	6 31/32	1 3/4	7 5/8	1 31/32	8 1/4	2 1/16	9 1/32	2 13/32	10 1/16	2 5/8	22
1 1/16		5 3/16	1 1/16	6 1/4	1 15/16	7 11/32	1 13/32	8 1/32	2 1/32	9 1/32	2 1/16	10 1/16	2 1/8	11 1/8	2 7/8	24
1 3/32		6 1/32	1 1/16	7 1/32	1 13/16	8 1/32	2 1/16	9 1/32	2 1/16	10 1/32	2 13/32	11 1/32	2 27/32	12 1/16	3 1/32	26
1 1/8		6 1/4	1 1/16	7 1/16	1 15/16	8 1/8	2 1/16	9 3/32	2 1/4	10 1/16	2 5/16	11 1/8	3 1/16	12 1/16	3 1/32	28
1 1/8		6 1/4	1 1/16	8 1/8	2 1/32	9 1/32	2 1/16	10 1/16	2 1/16	11 1/16	3	12 1/4	3 1/32	13 1/16	3 3/8	30
2		9 3/32	2 1/8	10 1/16	2 5/16	12 1/32	3 1/16	13 3/32	3 5/16	15 1/16	3 1/32	17	4 1/8	18 1/32	4 5/32	40
3		13 3/32	3 1/16	16 3/32	4 1/16	18 1/32	4 1/32	20 3/32	5 1/8	23 1/32	5 1/32	25 1/2	6 1/16	27 1/16	7 1/32	60
3 1/32		18 1/32	4 1/32	21 1/8	5 1/16	24 1/32	6 1/8	27 1/16	7 1/32	30 1/32	7 1/32	33 1/32	8 1/4	37 1/16	9 3/8	80
4 1/32		23 1/32	5 1/32	27 1/32	6 1/32	30 1/32	7 1/32	34 1/4	8 1/16	38 1/8	9 1/16	42 1/32	10 1/16	46 1/16	11 1/8	100

tion point will be the radii, for face and flank curves. Through these two centres and concentric with the pitch circle draw *circles of centres for face* and *for flank curves;* and with centres on these, and the respective radii found above, draw all tooth curves, and fillet the root corners to a radius of ·07 *p*, the clearance.

TO DRAW INVOLUTE TEETH APPROXIMATELY BY CIRCULAR ARCS.

Case I: The Rack.—Draw the pitch line and mark on it the pitch points. Draw limiting lines for the total height of the teeth, parallel to the pitch line. Through the pitch points draw *straight lines* for the sides of the teeth at 75° to the pitch line.

Case II: The Wheel.—Draw the pitch circle and mark on it the pitch points. Concentric with it, draw limiting lines for the total height of the teeth, and a *circle of centres* whose radius is $\frac{31}{32}$ or ·97 of the pitch radius. With centres on this circle and a radius equal to ·25 of the pitch radius, draw the face curves through the pitch points outward from the circle of centres, and finish the flanks by straight, radial lines, filleting the root corners to a radius of ·07 *p*.

CENTRAL STATION LIGHTING.*

By Pedro G. Salom.

The advantage of using storage batteries in central station lighting may briefly be summed up as follows:

(I) They effect a substantial saving in operating expenses.

(II) They increase the factor of safety.

(III) They permit of a material extension of distribution without increasing the size of the power plant.

(*I*) *As to the saving in operating expenses.*

As the question of economy is largely the determining factor as to the advisability of introducing a battery, let us examine more at length the means by which this is effected.

(*a*) By taking care of the crown of the maximum load when all the generating machinery is taxed to its utmost extent.

(*b*) By dispensing with one shift of labor in taking care of the entire minimum load.

(*c*) By permitting the operation of large units exclusively.

(*d*) By operating all the units at their maximum load and hence at their maximum efficiency.

As to the maximum load. Owing to the peculiar nature of electric lighting it frequently happens that the number of units generated at the maximum load is not more than a few per cent. of that of the total average load, and the total load is only a few per cent. in summer and rarely above forty per cent. in winter of the total possible output of the plant.

The first requisite, therefore, in determining whether a battery can advantageously be introduced in any given central station, and if so what its size or capacity shall be, is to have diagrams of the load curves.

The next important factor is the number and size of the units employed at the station. From these data we determine what has very appropriately been called the load factor, and then it is easy and simple to calculate the size of the battery required to give the most economical operating

* Read at the stated meeting of the Institute, held December 20, 1893.

results. Once the size of the battery is determined, we can calculate the saving effected:

(*a*) By dispensing with a night shift.

(*b*) By diminishing the consumption of coal for a given output.

(*c*) By the saving effected in operating a few large units of one size, instead of a number of small units of various sizes.

(*d*) By the saving effected in operating each unit at its maximum efficiency.

(*e*) By the additional revenues from increase of total output taken from battery at time of maximum load.

As the item of labor in small stations is frequently as high as twenty-five per cent. of the operating expenses, the saving effected by dispensing with a night shift is not inconsiderable.

By operating large units exclusively there is also a material saving effected both in labor and in the much higher efficiencies of large over small units.

Again, as the coal bill is the largest item of expense, amounting in some cases to more than fifty per cent. of the total operating expenses, any saving effected in this item is of paramount importance, and is reflected at once in the decrease of operating expenses.

The question of mechanical efficiency with varying loads has not been as carefully studied with each type of engine as its importance deserves, but Prof. W. Cawthorne Unwin, F.R.S., has shown that the decrease of mechanical efficiency for light loads has a serious effect on the economy of working with a variable load, and that with a load varying from 100 to 25 per cent. the efficiency decreases from eighty-five to forty per cent.

While it is impossible to say in a general way what the exact saving would be from the introduction of a battery of sufficient size to permit of the operation of all the units at maximum load (since the load is not the same in any two central stations), the results prove that in central stations equipped with storage batteries the operating expenses are diminished as much as thirty per cent.

(*II*) *As to the factor of safety.*

In case there is a derangement or break-down of the generating machinery, or where the steam pressure cannot be kept up to a sufficiently high point to operate all the units at maximum load, the elasticity of a storage battery permits of an immediate discharge rate enormously in excess of its normal rate. In other words, a battery designed for a given output could in emergencies be safely called upon for one half hour or more to deliver a current three times as great as that for which it was designed.

This is a fact of vital importance, and one which any central station man will at once appreciate, for in any direct system of transmission there is always the liability of a derangement or break-down of one of the links in the chain, whereas in a central station equipped with a storage battery the manager can depend on the battery to take the load of an individual unit until such time as the derangement or break-down can be remedied or repaired. Moreover, it frequently happens, where the business of a central station has increased since the original introduction of its generating machinery, that the boiler capacity at maximum load is so taxed that it is difficult to maintain steam pressure sufficient to operate all the units at once, in which case, if a battery is employed, recourse may be had to the battery until such time as the engineer shall be able to keep steam up to the required pressure.

(*III*) *As to the question of distribution.*

The advantages of the use of storage batteries under this head follow as a corollary from what has been said in the previous paragraphs, but the application is much wider than has been previously intimated. For example, when a central station has supplied the demand within a given radius of economical distribution and a demand arises for electric light or power immediately adjacent to and outside of this given radius of distribution, it is possible to supply this demand by having sub-stations of storage batteries. These may be charged by a special wire at comparatively high pressure during the day, thus increasing the average load of the central station, and their charge distributed at

night from the sub-stations at the regular pressure. The central station is thus enabled materially to increase its revenues without increasing its original power plant. An economy is effected also in this method of distribution by decreasing the size of the feeders to the outlying districts, since it is possible to charge the batteries used at a comparatively low rate for ten or twelve hours, whereas by direct lighting the feeders would have to be large enough to carry the entire load of the sub-station at its maximum output, which might only last for two or three hours.

In addition to the saving effected in operating expenses, the use of a battery may be made to yield additional revenues in proportion to the amount of current supplied to the circuit over and above what the direct system, at the time of maximum load, could supply without increasing the size of the power plant.

From what has been said above it is evident that central station lighting is one of the most important fields of usefulness of the storage battery and one which has hardly yet been touched upon.

The same arguments apply with increased force to its application in a power house for electric traction. Here the variation in the load is between such wide limits and of such a sudden character as to render it impossible to operate the power plant on anything like an economical basis.

In all such cases, by the introduction of a sufficiently large battery, the load curve, instead of resembling a stroke of lightning as it does at present, could be perfectly equalized, enabling the power plant to operate at full load and maximum efficiency.

The following list of central stations employing storage batteries in England and on the continent will give some idea of the extent of their adoption in those countries:

England.—Kensington Central Station, Gothenburg Electric Supply Company, Westminster Electric Supply Corporation (Limited), Knightsbridge Central Station, Houses of Parliament, Cadogan Electric Supply Company (Limited), Bradford Electric Supply Corporation (Limited), Liverpool Electric Supply Company (Limited), Northampton Electric

Light and Power Company (Limited), Notting Hill Electric Lighting Company (Limited), Southampton Electric Light and Power Company (Limited), Birmingham Electric Supply Company (Limited).

Germany.—Berlin (Thiergarten district); Königsberg, in Prussia; Stettin, Breslau, Hamburg, Lübeck, Bremen, Hannover, Erfurt, Cassel, Eisenach, Gera, Blankenburg, Osterade, Geestemünde, Düsseldorf, Barmen, Hagen, Gevelsberg, Gummersbach, Corbach, Marburg, Aix-la-Chapelle, Meiningen, Dessau, Bochum, Mühlhausen, Berchtesgaden, Hart, Zwickau, Hornberg.

Holland and Belgium.—Hague, Brussels, Dolhain, Ghent, Ninove, Westeras.

Sweden, Norway and Denmark.—Stockholm, Christiania, Copenhagen.

Italy and Spain.—Naples, Genoa, Ferrara, Madrid, Santander.

Switzerland.—Bern, Aarau.

France.—Paris, Secteur, Clichy, Lyons, Reims, Lille, Sedan.

TABLE NO. 1.—TYPE C. S.

Horse-power.	Kilowatts.	Voltage on Mains.	Maximum Rate of Discharge in Ampères.	Total Ampère-hour Capacity when Discharged in				Number of Accumulators in Series.	Number of Couples (Positive and Negative Plate) in each Accumulator.	Approximate Area in Square Feet Covered by Battery Alone.	Approximate Weight of Elements, in Pounds.
				3 hrs.	5 hrs.	7 hrs.	10 hrs.				
1	0·746	110	6	18	20	22	24	60	1	12	600
10	7·46	110	60	180	200	220	240	60	10	70	6,000
20	14·92	110	120	360	400	440	480	60	20	140	12,000
30	22·38	110	180	540	600	660	720	60	30	210	18,000
50	37·30	110	300	900	1,000	1,100	1,200	60	50	360	30,000
100	74·6	110	600	1,800	2,000	2,200	2,400	60	100	350	60,000
200	149·2	110	1,200	3,600	4,000	4,400	4,800	60	200	700	120,000
300	223·8	110	1,800	5,400	6,000	6,600	7,200	60	300	1,050	180,000
400	298·4	110	2,400	7,200	8,000	8,800	9,600	60	400	1,400	240 000
500	373·	110	3,000	9,000	10,000	11,000	12,000	60	500	1,750	300,000

NOTE.—The above table is based on sixty accumulators for a 110-volt circuit; for other potentials a proportionate number of accumulators is required.

TABLE NO. 2.—TYPE C. S.

Trade Number.	Number of Accumulators.	Number of Couples.	Voltage.	Time of Discharge, in Hours.	Rate of Discharge, in Amperes.	Ampere-hour Capacity at Different Rates of Discharge.	Horse-power.	Approximate Area in Square Feet Covered by Battery Alone.	Approximate Weight of Elements, in Pounds.
1	60	6	110	3	33	100	6	40	3,600
				5	22	111			
				7	17	122			
				10	13	133			
2	60	11	110	3	66	200	11	88	6,600
				5	44	222			
				7	35	244			
				10	26	266			
3	60	17	110	3	100	300	17	120	10,200
				5	66	333			
				7	51	366			
				10	40	400			
4	60	22	110	3	133	400	22	160	13,200
				5	88	444			
				7	68	488			
				10	53	532			
5	60	28	110	3	166	500	28	200	16,800
				5	111	555			
				7	87	610			
				10	66	665			
6	60	33	110	3	200	600	33	240	19,800
				5	133	666			
				7	104	732			
				10	79	798			
7	60	39	110	3	233	700	39	280	23,400
				5	155	777			
				7	122	854			
				10	93	931			
8	60	45	110	3	266	800	45	320	26,400
				5	177	888			
				7	139	976			
				10	106	1,064			
9	60	50	110	3	300	900	50	360	30,000
				5	200	999			
				7	157	1,098			
				10	119	1,197			
10	60	55	110	3	333	1,000	55	175	33,000
				5	222	1,110			
				7	174	1,220			
				10	130	1,330			
11	60	110	110	3	607	2,000	110	350	66,000
				5	444	2,220			
				7	350	2,440			
				10	266	2,660			
12	60	165	110	3	1,000	3,000	165	525	99,000
				5	666	3,330			
				7	523	3,660			
				10	400	4,000			
13	60	220	110	3	1,333	4,000	220	700	132,000
				5	888	4,440			
				7	697	4,880			
				10	532	5,320			
14	60	275	110	3	1,666	5,000	275	875	165,000
				5	1,110	5,550			
				7	872	6,100			
				10	665	6,650			

NOTE.—Nos. 1 to 9, inclusive, height, 9 inches. Nos. 10 to 14, inclusive, height, 18 inches. No allowance made for space between cells.

The above table is based on sixty accumulators for a 110-volt circuit; for other potentials a proportionate number of accumulators is required.

On the Determination of Phosphoric Acid.*

By H. Pemberton, Jr.

Last autumn I described a process for determining phosphoric acid by titration of the ammonium phospho-molybdate with standard alkali. (This *Journal*, **136**, 362.) The ratio between the P_2O_5 of the precipitate and the standard alkali was determined and found to be 23·2 molecules of Na_2O to one molecule of P_2O_5. Upon this ratio, as determined by direct analysis, the standard solution was prepared of such strength that one cubic centimeter should be equal to one milligram of P_2O_5 by diluting 326·5 cubic centimeters of normal alkali to one litre. The analyses upon which this ratio (23·2 molecules) was determined were carefully made. I was, therefore, at a loss to know the cause of the variation of this figure from the theoretical ratio of exactly 23 molecules of Na_2O. The difference is of more importance than might, at first thought, be supposed, because the strength of the alkali solution is based upon the figure determined empirically, and not upon the theoretical one. If the 23·2 proportion is wrong and 23 correct, a standard solution based upon the former ratio would give too low results in the proportion of 23·2 : 23·0. Thus, a phosphate rock containing 80 per cent. bone phosphate of lime would appear, by such an analysis, to contain only 79·31 per cent.

It was decided, therefore, to repeat this part of the work, and in this re-examination the conditions were the same as those previously existing, except in one particular: the amount of phosphoric acid operated upon was smaller than that previously used. By referring to the original paper, it will be found that about 80 cubic centimeters of alkali were used in each of the titrations in question. This represents a quantity of the yellow precipitate much larger than would ever be obtained in the examination of even the

* Read at the stated meeting of the Chemical Section, held February 20, 1894.

richest phosphate rocks; and in operating upon so large a precipitate the liability of error from incomplete washing is great. Any free acid remaining in the precipitate would, of course, result in too high a reading of the burette, with a corresponding error in the standardizing of the solution.

The following are the results obtained in this re-examination:

Some di-sodic hydric phosphate, bought as chemically pure, was dissolved in hot distilled water, filtered, and crystallized, the crystals were washed, dissolved again in water, and re-crystallized. Of the resulting crop of crystals, about 45 grams were dissolved in one-half litre of water. The strength of this solution was then determined

	Weight of Na_2HPO_4 Solution. Grams.	*Grams*	
I,	20·0814	gave 0·7581	$Na_4P_2O_7$
II,	17·9585	gave 0·6778	$Na_4P_2O_7$
III,	36·9115	gave 1·1652	$Mg_2P_2O_7$

The magnesium-ammonium phosphate precipitate was filtered, dissolved in acid and re-precipitated by ammonia.

By a coincidence each of these three determinations gave precisely the same result, viz:

TABLE I.

	Grams. P_2O_5 in 10 grams of Solution.
I,	= ·2014
II,	= ·2014
III,	= ·2014

Therefore, ten grams of the phosphate of soda solution contained 0·2014 grams P_2O_5.

Weighed portions of this same solution were now precipitated by ammonic molybdate, thoroughly washed and titrated. The results are given in Table II.

TABLE II.

I.	*II. Grams Na_2HPO_4 Solution taken.*	*III. Equivalent to Grams P_2O_5.*	*IV. CC. of KHO Solution used.*
A,	2·0410	0·04110	41·05
B,	2·3710	0·04775	47·70
C,	2·2920	0·04616	46·20
D,	2·4690	0·04972	49·60

Dividing the figures in Column III by those in Column IV, and multiplying the result by 100, we obtain the number of milligrams corresponding to 100 cubic centimeters of the KHO solution, as follows:

TABLE III.

	Mgrs. P_2O_5
A,	= 100·12
B,	= 100·11
C,	= 99·91
D,	= 100·24
Average,	= 100·09

Therefore, 100 cubic centimeters of the KHO solution neutralize an amount of the yellow precipitate corresponding to 100·09 milligrams of P_2O_5.

The standard acid was now titrated against the standard alkali, using phenolphthalein as the indicator, whereby the two solutions were found to be of exactly equal strength.

The standard acid was then titrated against pure sodium carbonate, using phenolphthalein at boiling heat:

	Grams Na_2CO_3 used.	*CC. of Acid used.*	*100 cc. Acid equal to Mgrs. Na_2CO_3.*
I,	0·9099	52·95	1,719
II,	0·9168	53·35	1,719

Therefore, 100 cubic centimeters acid are equivalent to 1,719 milligrams Na_2CO_3, and since the alkali solution is of the same strength as the acid, 100 cubic centimeters of it also are equivalent to 1,719 milligrams Na_2CO_3.

As we have already seen, by Table III, that 100 cubic centimeters of the alkali are required to neutralize 100·09 milligrams of P_2O_5 (in the form of ammonium phospho-molybdate), it follows that 1,719 milligrams Na_2CO_3 are required for 100·09 milligrams P_2O_5.

Dividing each by its molecular weight, we have

$$\text{for } P_2O_5 \quad \frac{100{\cdot}09}{142{\cdot}06} = {\cdot}7045$$

$$\text{for } Na_2CO_3 \quad \frac{1{,}719}{106{\cdot}1} = 16{\cdot}20$$

Therefore,

$$P_2O_5 : Na_2CO_3 = {\cdot}7045 : 16{\cdot}20 = 1 : 22{\cdot}99$$

In other words, 23 molecules of Na_2CO_3 (or of Na_2O) are required to neutralize the yellow precipitate containing one molecule of P_2O_5, and the former figure (that given in my paper of last autumn) 23·2 molecules, is incorrect.

Referring to Table II of the present paper, it may be stated that in Analysis A the yellow precipitate was washed on an ordinary filter without using suction, the precipitate being washed on the filter, transferred to the beaker and then again filtered and washed. In Analysis B, of the same table, the precipitate was washed on the ordinary filter, with the aid of the suction pump. In Analyses C and D, the precipitates were washed with suction on a porcelain funnel with a fixed perforated plate in it. This form of funnel is known as the Hirsch funnel.*

As in all cases the results were nearly identical, it is evident that the different methods of washing the precipitate had no influence upon the result. Exactly twenty-three molecules of Na_2O are required for one molecule of P_2O_5. The standard acid is prepared by diluting 323·7 cubic centimeters of normal sulphuric acid to one litre, and not 326·5 cubic centimeters, as previously stated. The alkali solution, after removing CO_2 by $Ba(HO)_2$, is brought to the same strength as the acid, volume for volume.

One cubic centimeter of either solution is then equal to one milligram of P_2O_5.

PHILADELPHIA, PA.,
February 20, 1894.

*To be had from Bullock & Crenshaw, Philadelphia. A disc of filter paper of the diameter of an American silver quarter dollar (fifteen-sixteenths inch) is used, when employing the smallest size funnel. I can highly recommend this funnel in all cases in which the precipitate is to be titrated. The precipitate presents a perfectly flat surface, is easily and quickly washed, and is readily transferred to the beaker with the aid of the wash-bottle. This funnel can be employed only when using the suction pump, but it has the advantage of not requiring a platinum cone, and the size of the filter is reduced to a minimum.

THE RESISTANCE OF SHIPS.

BY RICHARD LANO NEWMAN.

[*A paper read before the Section of Engineers and Naval Architects January 24, 1894*]

[*Concluded from p. 233.*]

Up to the present we have assumed that the stream lines retain their horizontal flow, but it would be as well to state that this is not generally accepted as correct.

Scott Russell says: "At the foremost part of a ship the particles move in layers which are almost horizontal, while at the stern the particles have a considerable vertical component in their motion, besides converging laterally." How this vertical component can exist only at the stern and not at the bow, seems to me to be altogether unaccountable. There must of necessity have been a source of supply to have obtained this vertical component, and that supply could only have been obtained by the existence of corresponding conditions at the bow. It, therefore, seems that Professor Rankine's conclusions are more nearly correct. He says: "The actual paths of the particles of water in gliding over the bottom of a vessel are neither horizontal waterlines nor vertical buttock lines, but are intermediate in position between those lines, and approximate in well shaped vessels to the lines of shortest distance, such as are followed by an originally straight strake of plank, when bent to fit the shape of the vessel!" But, whatever paths may be followed, if the particles, at a considerable distance astern of a ship wholly submerged in a frictionless fluid, have regained their original direction and speed of flow, which they had at a considerable distance ahead of the ship, then their flow past the ship will impress no end-wise motion upon her.

Professor Rankine has laid down geometrical rules for constructing the paths along which the particles of a fric-

tionless fluid would flow in passing a body very deeply submerged, but as it would occupy too much time to investigate the subject, I would refer those desirous of doing so to pages 106-107, of his *Ship-building, Theoretical and Practical.*

As before stated, a frictionless fluid, on passing a body wholly submerged, will impress no end-wise motion upon her, nor (providing she is submerged sufficiently deep) will there be any surface disturbances, but this last-named condition does not hold good in a body only partly immersed, as is a ship. At the bows the streams will receive a check in their velocity. This check means an increase of pressure, and hence a wave-crest will be formed at the bow. Amidships, where the conditions are reversed, that is, where increase in the velocity of the stream lines means decrease of pressure, the water might fall some distance below its normal level. At the stern, where the conditions are somewhat similar to those at the bow, another wave-crest will be formed. There are other waves which would probably exist between bow and stern, and to which I propose to refer at a later stage, should time permit. Every one readily sees why a wave is formed at the bow, but it is more difficult to account for the existence of one at the stern. The reasoning generally accepted for the one is is also assumed to hold good for the other, viz: The surface of the water is subjected to a uniform pressure, *i. e.*, atmospheric pressure, and any diminution or increase of pressure caused by the fluctuation of the speed of flow past the ship, will be apparent by a depression below, or a piling up above, the level of the surrounding waters; hence, we have the depression amidship and the bow and stern waves. Mr. Froude estimates that the frictional resistance in a well formed ship, 160 feet long, from and up to a speed of six and ten knots, is eighty or ninety per cent. of the total resistance. He instances another case, in which the wave-making resistance of a ship at thirteen knots was only seventeen per cent. of the whole; but when travelling at nineteen knots it became fully sixty per cent. of the total resistance. We therefore see what huge proportions the wave-making resistance of a ship will assume, and it challenges all the

skill of our naval architects of to-day to reduce this factor to a minimum.

Allow me a word on eddy-making resistance before passing on. It is generally agreed that in well formed ships with easy curves at the entrance and run (more especially the latter), this factor in the resistance of a ship is comparatively unimportant, and Mr. Froude estimates eight per cent. of the frictional resistance as a very liberal allowance; but its amount will of course depend on the lines of the ship, especially that of the run. No general rule can be laid down; but Mr. Froude says eddies are caused rather by blunt tails than by blunt noses.

Having taken a brief, and, of necessity, a very imperfect survey of the several items which constitute the total resistance of a ship, apart from what is usually known as the augment of resistance, let us now take them separately and investigate the conditions governing each.

I will first draw your attention to the resistance usually known as "frictional resistance." The experiments from which our deductions are drawn are those which were conducted at London in the years 1796 and 1798. I take these, rather than those of a later date, principally to show how very slow we are to grasp and adopt experimental facts.

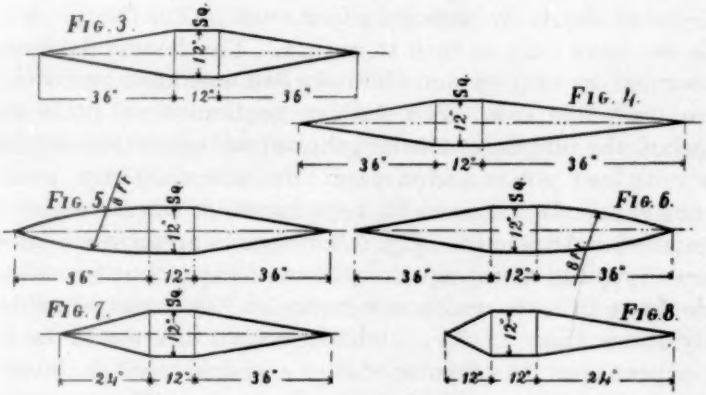
Figs. 3 to *8*, inclusive, are the forms I have taken for comparison, and for convenience the results are stated in the fractional form, thus:

$$\frac{\textit{Resistance.}}{\textit{Capacity.}}$$

The bodies were drawn through still water at velocities ranging from one to eight nautical miles per hour, and the comparisons we make will be at a velocity of five nautical miles, as those bodies that showed to advantage at this velocity maintained their superiority at the higher speeds. The value of the resistance of the several bodies will be found in the following table:

	Fig. 3.	*Fig. 4.*	*Fig. 5.*	*Fig. 6.*	*Fig. 7.*	*Fig. 8.*
Resistance,	1	1	1	1	1	1
Capacity,	15·175	17·895	17·482	?	12·244	10·014

Figs. 3 and *4* are identical, with the exception that the after body of *Fig. 3* was taken off and replaced by another, 1 foot 6 inches longer, with the result that the mean resistance fell from $\frac{1}{15 \cdot 175}$ to $\frac{1}{17 \cdot 895}$. At first sight it appears paradoxical that by increasing the length of a body we can reduce its mean resistance. Mr. Froude, who made numerous experiments on this subject, explains this important experimental fact as follows: The portion of surface that goes first in the line of motion in experiencing resistance from the water, must in turn communicate motion to the water in the direction in which it is itself travelling, consequently the portion of the surface which succeeds the first



will be rubbing, not against stationary water, but against water partially moving in its own direction, and cannot, therefore, experience as much resistance from it. It therefore follows that the length of surface considerably affects its mean resistance, but he also showed by his experiments that there is a limit to the advantages accruing from increased length. Lengths of fifty feet, when compared with considerable shorter lengths, showed to decided advantage, but lengths over fifty feet, when compared with lengths of fifty feet showed about the same mean resistance. I presume there are a number here present who have heard of a case where a ship was lengthened and her final performance decidedly improved thereby. This, in itself, is a

practical illustration of this fact. A few years ago, the practice of lengthening ships was greatly overdone, and ofttimes the seaworthiness of the ships was jeoparded in this attempt to reduce the mean resistance.

Fig. 5 is the same as *Fig. 3*, with the exception of the slightly increased fulness at the entrance. On referring to the table, we see that the mean resistance of *Fig. 5* is very little less than that of *Fig. 4*, and is much less than that of *Fig. 3*. Now, how can we account for this superiority over *Fig. 3*? The only satisfactory answer seems to me to be that *Fig. 5* is a nearer approach to the form of least resistance for a body wholly submerged. I say advisedly, wholly submerged, for other conditions would have to be considered if the body was only immersed. For the proof of this we have only to turn to nature. The fastest fishes are so formed as to give a moderately full entrance and a very clear and fine run. The fullest section is a little forward of the middle of the length, but we know that the fish does its best when under water, not when on top, consequently this fact should be kept in mind, when the fish is compared with a ship. *Fig. 6* for speeds up to seven knots showed results about equal to those of *Fig. 3*, but for velocities above this the mean resistance of *Fig. 6* rose considerably above those of *Fig. 3*, which is what one would be led to expect after the results of *Fig. 4*, and is another illustration of the necessity of having a clear run. The increased resistance of *Fig. 6* at the high velocities is no doubt due to eddies caused by the abrupt termination of the after body. In *Figs. 7* and *8* there is a decided increase in the resistance, caused, of course, by the change in the proportion of the forebody, and due principally to the abrupt change of motion at the junction of the fore and middle body. I can imagine a considerable wake following on each side, caused by the waters eddying round the forepart of the middle body, which would mean a virtual increase in the capacity of the body, and I think we shall be safe in concluding that the principal cause of the difference in the resistance of the several bodies is the abruptness in the change of flow. Had the bodies been moderately rounded off, to conform more nearly

to the shape of a ship, there would still have been a difference in their several resistances, but not so great a difference as is here shown.

Summing up the foregoing remarks, it seems: That frictional resistance depends upon the area of the immersed surface of a ship, its degree of roughness, its length, and varies nearly with the square of the speed. It is not sensibly affected by the form or proportion of the ship, unless the form differs widely from the usually accepted ship shaped body; and for moderate speeds this element of resistance occupies by far the most important position, rising in some instances as high as seventy and eighty per cent. of the total resistance. By moderate speeds we mean those speeds most suited for the dimensions of the ship under consideration.

Wave-making Resistance.—This, as before stated, will depend on the velocity, the form of the bow and stern, and the breadth of the ship relatively to her length. It is obvious on reflection that the length as well as the form of entrance and run must greatly influence both bow and stern waves. During each interval occupied by a ship in advancing through a distance equal to the length of her entrances, the sets of particles then contiguous thereto undergo accelerations which lead to the production of the bow wave. This interval of time depends upon the ratio of the length of entrance to the speed of the ship. Similar importance attaches to the ratio between the length of run and the speed. Hence, for every speed there is a certain length of entrance and run, below which it is not advisable to go if the wave-making resistance is to be kept at a minimum.

One eminent authority states: "If the lengths of entrance and run are not suitably adjusted to the maximum speed of the ship, the waves which are formed, or a certain portion of them, diverge from her path, carrying off into still water the energy impressed upon them. The ship has, therefore, to be continually creating new waves, and, when the speed of a ship exceeds that of the waves which her entrance and run naturally tend to form, other series of waves makes its appearance, even more important than the diverging

waves. They have a length proportional to the speed of the ship, and actually keep pace with her."

It being universally admitted that for every vessel there is a speed beyond which increase of speed is obtained only by an enormous expenditure of power, let us now see what are the usually accepted proportions of length of entrance and run to the velocity. Mr. Scott Russell gives us in his *Naval Architecture :*

$$L_1 = 0{\cdot}562 \times V^2$$

$$L_2 = 0{\cdot}375 \times V^2 = \tfrac{2}{3} L_1$$

where L_1 = length of entrance, V the maximum velocity in knots per hour, and L_2 the length of run.

With these lengths Mr. Scott Russell considered there might be associated any required length of middle-body the additional resistance for the assigned speed being chiefly due to friction on the enlarged immersed surface.

Many successful ships have been built on the foregoing proportions, and in cases where the entrance has been smaller the results have been equally good; but ships having a smaller proportion of run have not been a success.

A great number of very successful ships have been built upon a modification of the foregoing rule, in which the length of entrance and run are equal:

$$L_1 + L_2 = 0{\cdot}937\ V^2$$

whence

$$V^2 = 1{\cdot}067\ (L_1 + L_2)$$

and

$$V = 1{\cdot}03 \sqrt{L_1 + L_2}$$

nearly.

Having now satisfied ourselves that there is a suitable length for any given speed, let us see what are the conditions governing the breadth of the ship and the shape of the entrance and run. That is to say, what are the most suitable lines, a full easy curve as we see adopted on our Atlantic liners, or a hollow curve as usually seen on our high-speed war ships; and, if there is a reason why the difference should exist, what is that reason?

The following table of particulars relating to several ships, will furnish the data for our consideration of the question.

Ships.	Length.	Breadth.	Mean Draft.	Displacement.	Length / Breadth.	Coëf. Fineness.	I. H. P.	Full Speed.	I. H. P. per Ton of Displacement for 10 Knots.	Remarks.
	feet.	*feet.*	*feet.*							
Livadia, ...	235	153	7⅛	4,400	1·537	·571	12,350	15·725	·477	3 screws.
Iris, ...	300	46	18	3,290	6·521	·463	7,500	18·	·304	
Victoria and Albert,	300	40¼	14	2,000	7·45	·4115	3,200	17·	·300	
Charles Quint, . . .	315	33½	14 5-6	2,480	9·4	·554	2,400	16·	·202	
Edgar, ...	360	60	23½	7,350	6·	·506	12,961	20·97	·136	
Blenheim, ...	375	65	25¾	9,000	5·77	·502	21,600	21·	·156	Trial in shallow water.
City of New York, .	525	63¼	25	10,500	8·3	·443	20,000	20½	—	Approximate.
U. S. New York, . .	380	66¼	23 10¾	8,480	5·91	·509	17,000	21·	—	
Columbia, ...	—	—	—	—	—	—	—	—	—	
Teutonic, ...	582	57 ft. 6 in	—	—	—	—	—	—	—	
Torpedo Boat, ...	137	13¾	4	86	9·9	·4	1,203	21·	1·37	

Several of the speed curves have been plotted from data obtained from *London Engineering*.

Let us first see how the lengths of these ships compare with the combined lengths of entrance and run necessary to satisfy the last rule:

	Speed.	Length.	$L_1 + L_2 = 0{\cdot}937\ V^2$
		feet.	
Livadia, ...	15·725	235	231·69
Iris, ...	18·	300	303·58
Victoria and Albert, ...	17·	300	270·75
Charles Quint, ...	16·	315	230·5
Edgar, ...	20·97	360	413·2
Blenheim, ...	21·	345	413·
City of New York, ...	20·5	525	393·7
Torpedo boat, ...	21·	137	413·

On looking at the *Livadia*, we see she has a length of 235 feet, displacement of 4,400 tons and a coëfficient of fineness of

·571, all very reasonable dimensions, and the length seems specially adapted for her speed, but when we look at the other dimensions we find most astonishing proportions, viz: a draft seven and one-half feet and a ratio of length to breadth 1·537. Taking seven knots as a reasonable velocity, and one

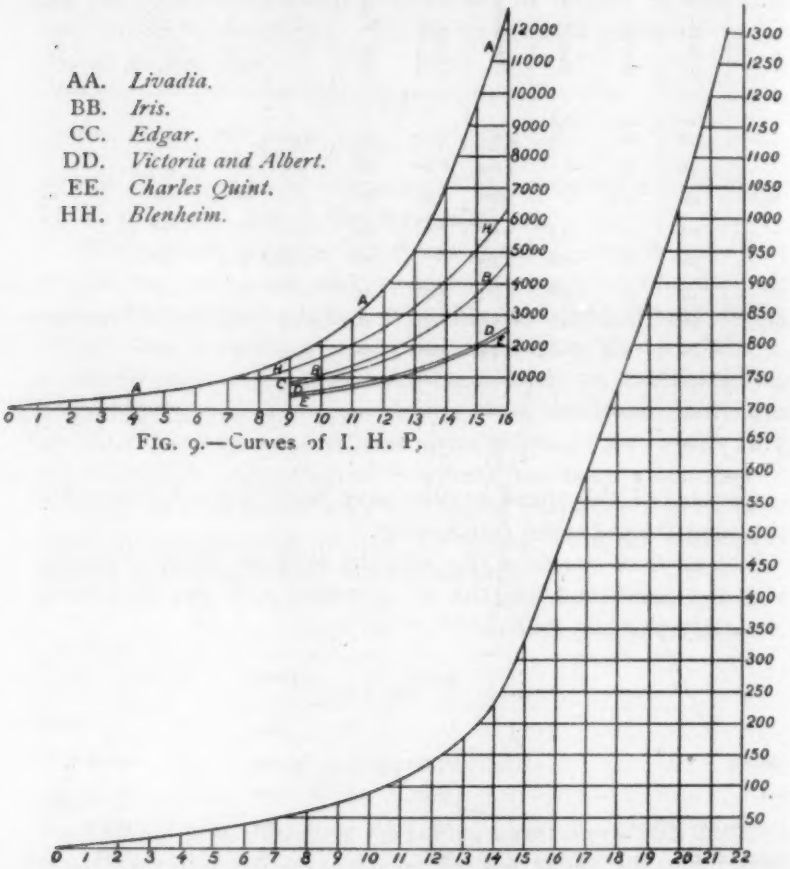


FIG. 9.—Curves of I. H. P.

FIG. 10.—Curve of I. H. P. for torpedo boat.

at which the frictional resistance is normal, we find that at ten knots that resistance is approximately as the square, but is rapidly rising, until at thirteen knots it is approximately as the cube. It is unnecessary to comment on the great proportionate expenditure of power as compared with the other

vessels, but it should be noted that her displacement, being greater than that of the other ships, somewhat favors her in the comparison of the ratio of horse-power to displacement; but the difference will be found to be considerable on referring to the column containing the results of indicated horse-power per ton of displacement for ten knots. The question naturally arises, what is the cause of this abnormally high expenditure of power? And could the proportions of the ship have been so modified as to give more satisfactory results? The answer to these questions is, that on the same displacement the ratio of length to breadth could have been considerably increased by increasing the mean draft, and much more satisfactory results obtained. What the draft or the ratio of length to breadth should have been, we are not yet in a position to state; but the lesson taught is, that if the necessity arises, in vessels of moderate speed and a given length and displacement, it is possible to exchange the ordinary form of midship section, for a very broad, shallow section of equal area, and, by favoring a considerable fineness in the buttock and bow-lines, to obtain the given speed with from thirty to fifty per cent. more power than would be required for ships of ordinary form. The proof of this we have in the stern-wheelers, built by Yarrow & Co., London, and also in the numerous shallow steamers navigating the waters of the many rivers of this country. But there is decidedly a ratio of length to breadth below which it would not be advisable to go. In the case of the *Livadia*, there was no doubt a considerable loss of power due to the abruptness of the lateral deflection of the stream lines, which would result in forming excessive waves and wake.

The *Iris* in her day was considered an exceptional ship, and her dimensions contrast most favorably with ships of more modern construction. There is one thing, however, that we should remember when making comparisons between ships of a comparatively early date and those of to-day, namely, that the machinery for these older ships was designed for much lower pressures and would consequently be much heavier and more clumsy than those of

to-day. The engines of the *Iris*, at full speed, ran at about ninety revolutions per minute, and the power necessary to overcome the constant friction of the machinery at this speed would be about from eight to ten per cent. of the total indicated horse-power; whilst at from nine to ten knots it would require about thirty per cent. of the indicated horse-power. This would also apply to the *Victoria and Albert*, she being fitted with the old oscillating style of engine, running at about thirty revolutions. The augment of resistance in the *Victoria and Albert* would also be increased, owing to the extra friction caused by the flow of the paddle race past the sides. All these points should, therefore, be considered when making comparisons. Looking now at the results obtained by the *Edgar* and the *Blenheim*, we are forced to the conlusion that they are real and marvellous triumphs of modern skill. The *Edgar* is carrying one ton on about 1·76 indicated horse-power, at about twenty-one knots. The *Blenheim*, under most unfavorable conditions, is carrying one ton on 2·4 indicated horse-power at twenty-one knots. The liner *New York* carries one ton on 1·9 indicated horse-power, and at a speed of 20·5 knots, a performance about the same as that of the *Blenheim*, and very much inferior to that of the *Edgar*. The question that naturally arises in one's mind is, if on the dimensions of the *Edgar* we can carry one ton with smaller expenditure of power than we can on the dimensions of the liner *New York*, why should we resort to the longer form? And why do we hear so much about ships of 600, 800 and 1,000 feet long, to cross the Atlantic in four days, if the results can be obtained with ships of more moderate dimensions, having a smaller proportion of length to breadth, and by employing much finer extremities, such as the hollow water lines which usually obtain in high-speed war cruisers and torpedo catchers.

In comparatively smooth water, when going at full speed, the liner *New York* rolled considerably. Now it seems to me that in a ship of more moderate dimensions the period and amplitude of the oscillation could be greatly reduced; and in a passenger ship this point should have some weight.

Ships, like the *Campania* and *Lucania*, which have a length more than ten times their depth, vibrate considerably.

The cruiser *New York* developed a speed of twenty-one knots on an indicated horse-power of 17,000, and a displacement of 8,480 tons. This is equivalent to 2·12 indicated horse-power per ton of weight at twenty-one knots, and on referring to her photographs, taken when on her full speed run, you will see by the proportions of her bow and stern wave, that she had about reached the limit of her speed; this is also discernible in the very steep rise of her speed curve at this speed. If, on the dimensions of the cruiser *New York*, we can obtain such excellent results, should we not be justified in expecting as good results from the liner *New York* with length, 413 feet on water line, 70 feet extreme breadth and 25 feet mean draft of water, or with mean draft increased to 28 feet and the beam correspondingly reduced to suit.

The results obtained from the torpedo boat show what a severe penalty we pay in order to obtain high velocities from exceptionally short bodies. At twenty-one knots we absorb no less than fourteen indicated horse-power per ton of displacement.

BOOK NOTICE.

Lecture Notes on Theoretical Chemistry. By Ferdinand G. Weichmann, Ph.D. First edition. New York: John Wiley & Sons. 1893.

This volume is an elementary treatment of the subjects embraced in what is covered by theoretical chemistry, as the term is at present understood. The treatment appears to us to be unusually well adapted for the comprehension of students of chemistry, and the lecture notes will probably be warmly welcomed by instructors in the science. The author is an instructor in chemical physics at Columbia College, and the lecture notes have evidently been evolved into book form on account of the need felt for such a comprehensive treatment of the subject. The introduction of practical problems in connection with each chapter adds substantially to its value for the class of readers for whom the book has been prepared, and the elaborate bibliographical list at the close of the volume will serve as an excellent guide for the ambitious student who may desire to extend his studies of the subject.

W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 21, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1894.

JOSEPH M. WILSON, President, in the chair.

Present, seventy members and five visitors.

Additions to membership since last report, twenty-one.

The Secretary presented a communication from Mr. George F. Kunz, Secretary of a Joint Committee on Coinage of the National Sculpture Society and the Numismatic and the Archæological Society, requesting the appointment by the Franklin Institute of a committee to represent it in the Joint Committee. The objects of this committee, briefly stated, are to endeavor to bring about an improvement in the design of our national coins in the interest of good art, and to secure the application of the metric system to the coinage.

It was the sense of the meeting that the objects named in the communication were not directly germane to the purposes of the Institute, and accordingly no action was taken.

Mr. E. P. Holly, of Providence, R. I., presented a paper describing a "Gravity Return System," of his invention, for automatically returning water of condensation to steam generators, where the latter are situated above the level of the attachments to be drained. The author illustrated his paper by the exhibition of a number of diagrams, showing various modes in which his invention could advantageously be applied in practice.

The paper was freely discussed by Mr. Walter H. Kerr, Mr. Spencer Fullerton, the author and others.

The Secretary exhibited, with the aid of the lantern, views of plans for underground and elevated railways at present under consideration, or in course of execution, in the cities of New York and Boston.

The Secretary made allusion to the proposition of Mr. F. L. Stewart, of Murraysville, Pa., for utilizing the corn cane as a source of sugar, and gave a brief statement of the facts observed by him and upon which he bases the claim that the corn cane may be utilized with profit as a sugar plant.

The Secretary stated that the publications of Mr. Stewart on this subject had attracted an unusual amount of attention because of their bearing on one of the greatest of our industries, and that, in order to be prepared to answer several inquiries he had received in relation to them, he had requested, and obtained, the opinion of an expert occupying a responsible official position under the Government, and who was in all respects qualified to judge of the value of Mr. Stewart's facts and propositions.

The Secretary regretted to have to state that, in this expert's opinion, the facts on which Mr. Stewart's propositions are based are misleading, and the prospects for utililizing the corn stalk as a commercial source of sugar, too unpromising to be worthy of serious consideration.

Adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

T. F. TOWNSEND, WEATHER BUREAU, L. F. O. IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR FEBRUARY, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 28, 1894.

GENERAL REVIEW.

February's normal temperature and rainfall is about 30°·0 and 3·51 inches. The present month has been 2°·4 colder than the average, and the rainfall ·02 more.

The warmest days were the 8th, 9th, 10th, 18th, 19th and 28th, and the coldest on the 17th and 25th. The lowest temperatures recorded were Dyberry minus 24° and Honesdale minus 20°.

The snowfall was quite heavy for February and occurred on several days. The largest totals in inches were Salem Corners, 42·3; Somerset, 40·2; Blue Knob, 38·5, and Kilmer, 37·3. Nearly all stations report snow on ground at the end of the month.

A fine auroral display occurred on the 23d.

From January 1, 1894, to February 28, 1894, the excess in temperature at Philadelphia was 67°; Pittsburgh, 165°; and Erie, 120°.

For the same period the deficiency in precipitation at Philadelphia was 1·75; Erie, 1·31, and Pittsburgh, 0·96.

	Mean Temperature.	*Mean Precipitation Inches.*
February, 1888, ...	28°·4	2·50
1889, ...	23°·0	1·96
1890, ...	37°·1	4·32
1891, ...	34°·9	4·61
1892, ...	31°·7	1·75
1893, ...	27°·4	5·92
1894, ...	27°·6	3·53

NOTE.—Crop correspondents are requested to resume their reports the first week in April Blanks furnished on application.

TEMPERATURE.

The mean temperature for February, 1894, was 27°·6, which is 2°·4 below the normal, and 0°·2 above the corresponding month of 1893.

The means of the daily maximum and minimum temperatures, 36°·4 and 18°·9, give a monthly mean of 27°·6, with an average daily range of 17°·5.

Highest monthly mean, 36°·3 at Altoona.

Lowest monthly mean, 20°·2 at Dyberry.

Highest temperature recorded during the month, 64° on the 6th at Pittsburgh.

Lowest temperature, minus 24° on the 26th at Dyberry.

Greatest local monthly range, 73° at Dyberry.

Least local monthly range, 48° at Altoona and Harrisburg.

Greatest daily range, 56° at Ligonier.

BAROMETER.

The mean pressure for the month, 30·15, is about ·05 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·86 at Philadelphia, on the 24th, and the lowest 29·46 at Erie on the 9th.

PRECIPITATION.

The average rainfall, 3·53 inches for the month, is an excess of 0·02.

The largest monthly totals in inches were Reading, 5·59; Somerset, 5·20; Kennett Square, 5·08; Blue Knob, 4·97, and Salem Corners, 4·90.

The least were Greenville, 1·62; New Castle, 1·76; Altoona, 1·82, and Grampian, 2·14.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 11; clear days, 8; fair days, 9; cloudy days, 11.

MISCELLANEOUS PHENOMENA.

Thunder.—Quakertown, 19th; West Chester, 19th; Coatesville, 19th; Kennett Square, 19th, 25th; Phœnixville, 19th; Erie, 25th; Lancaster, 19th; Kane, 10th; Pottstown, 19th; Easton, 19th; *Philadelphia* [Weather Bureau], 19th; [Centennial Avenue], 19th; [Locust Street], 20th; York, 20th.

Hail.—Kennett Square, 25th; Phœnixville, 12th, 15th, 19th, 26th; Lebanon, 12th, 26th; Philadelphia [Centennial Avenue], 19th; Dyberry, 9th; York, 12th, 13th, 20th, 26th.

Snow.—Altoona, 1st, 3d, 4th, 9th, 12th, 13th, 15th, 18th, 26th, 27th; Blue Knob, 1st, 4th, 12th, 13th, 15th, 16th, 19th, 23d, 25th, 26th; Hollidaysburg, 1st, 4th, 12th, 13th, 15th, 25th, 26th; Quakertown, 1st, 4th, 10th, 14th, 15th, 16th, 22d, 25th, 26th; Johnstown, 1st, 4th, 12th, 13th, 14th, 15th, 16th, 25th, 26th; Emporium, 1st, 4th, 10th, 12th, 13th, 14th, 15th, 18th, 19th, 21st, 23d, 26th; East Mauch Chunk, 1st, 4th, 12th, 13th, 15th, 26th; State College, 1st, 4th, 12th, 13th, 15th, 26th; West Chester, 4th, 12th, 13th, 15th, 22d, 25th, 26th; Coatesville, 4th, 12th, 13th,

14th, 15th, 22d, 25th, 26th; Phœnixville, 1st, 12th, 13th, 14th, 15th, 25th, 26th; Westtown, 1st, 4th, 12th, 13th, 22d, 25th, 26th; Grampian, 1st, 3d, 9th. 13th, 15th, 26th; Lock Haven, 1st, 4th, 12th, 13th, 15th, 26th; Bloomsburg, 1st, 4th, 12th, 13th, 14th, 15th, 26th; Carlisle, 1st, 4th, 12th, 13th, 14th, 15th, 26th; Swarthmore, 4th, 13th, 22d, 25th, 26th; Huntingdon, 1st, 4th, 12th, 13th, 15th, 26th; Kilmer, 1st, 4th, 12th, 13th, 26th; Lancaster, 4th, 12th, 13th, 15th, 26th; Lebanon, 1st, 3d, 4th, 12th, 13th, 14th, 15th, 19th, 25th, 26th; Coopersburg, 1st, 4th, 12th, 13th, 14th, 15th, 25th, 26th; Drifton, 1st, 2d, 4th, 10th, 12th, 15th, 16th, 19th, 20th, 24th, 27th; Wilkes-Barre, 1st, 4th, 13th, 15th, 26th; Kane, 1st, 12th, 13th, 15th, 23d; Smethport, 1st, 4th, 12th, 13th, 15th; Greenville, 1st, 4th, 12th, 13th, 15th, 26th; Pottstown, 1st, 4th, 12th, 14th, 21st, 25th, 26th; Easton, 1st, 4th, 14th, 15th, 16th, 26th; Logania, 1st, 4th, 12th, 13th, 14th, 15th, 25th, 26th; *Philadelphia* [Centennial Avenue], 1st, 4th, 12th, 13th, 15th, 22d, 25th, 26th; [Locust Street], 1st, 4th, 12th, 13th, 15th, 22d, 25th, 26th; Blooming Grove, 2d, 10th, 13th, 16th, 19th, 26th; Shingle House, 1st, 4th, 9th, 10th, 12th, 13th, 15th, 16th, 23d; Selins Grove, 4th 12th, 13th, 15th, 26th; Somerset, 1st, 3d, 4th, 5th, 12th, 13th, 15th, 16th, 26th; Wellsboro, 1st, 4th, 9th, 12th, 13th, 15th; Lewisburg, 1st, 3d, 12th, 13th, 15th, 26th; Dyberry, 1st, 4th, 9th, 12th, 13th, 14th, 15th, 16th, 20th, 26th; Honesdale, 1st, 4th, 9th, 12th, 13th, 15th, 20th, 26th; Salem Corners, 1st, 4th, 5th, 9th, 12th, 13th, 14th, 15th, 20th, 26th, 27th; Immel Reservoir, 5th, 12th, 16th, 26th; Ligonier, 1st, 4th, 13th, 14th, 15th, 26th; York, 4th, 12th, 13th, 15th, 22d, 25th, 26th.

Sleet.—Kennett Square, 15th; Phœnixville, 15th; Westtown, 12th, 15th, 26th; Lock Haven, 7th; Lebanon, 19th, 26th; Coopersburg, 12th, 26th; Logania, 3d, 12th, 19th, 26th; Philadelphia [Centennial Avenue], 12th, 13th, 19th; Somerset, 12th, 26th; Dyberry, 9th; York, 26th.

Aurora.—Hollidaysburg, 24th; Emporium, 23d; Mauch Chunk, 23d; State College, 22d, 23d; West Chester, 23d; Coatesville, 23d; Kennett Square, 23d; Phœnixville, 23d; Westtown, 23d; Lock Haven, 23d, 24th; Harrisburg, 23d; Swarthmore, 16th; Coopersburg, 23d; Wilkes-Barre, 22d; Philadelphia, 23d; [Centennial Avenue], 23d; Shingle House, 21st, 28th; Selins Grove, 23d; Somerset, 22d; Wellsboro, 23d; Lewisburg, 15th, 18th, 20th; Dyberry, 23d; York, 23d.

Coronæ.—Saegerstown, 16th; Salem Corners, 18th, 20th.

Solar Halo.—Le Roy, 5th, 8th, 20th, 25th 28th; *Philadelphia* [Weather Bureau], 17th, 24th, 25th; [Centennial Avenue], 24th, 25th; [Locust Street], 17th, 24th; Wellsboro, 17th, 19th, 28th.

Lunar Halo.—State College, 17th, 18th; Uniontown, 15th, 17th; Lancaster, 20th; *Philadelphia* [Weather Bureau], 15th, 18th; [Centennial Avenue], 15th, 18th; [Locust Street], 15th, 18th.

APRIL WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future April.

	Philadelphia. (22 years.)	Pittsburgh. (23 years.)	Erie. (20 years.)
Mean or normal,	51°	51°	44°
Warmest April,	1871	1878	1878
Average,	57°	57°	54°
Coldest April,	1874	1874	1874
Average,	42°	42°	37°
Highest temperature recorded,	91°	89°	86°
Date,	30th, 1888	23d, 1885	14th, 1883
Lowest temperature recorded,	18°	14°	11°
Date,	12th, 1874	13th, 1875	5th, 1881
Average date of last "killing" frost (spring),	April 9th	April 27th	April 30th
Average precipitation (inches),	2·87	2·70	2·56
Average number of days with ·01 inch or more,	11	14	13
Greatest monthly precipitation,	9·76	7·20	3·86
Date,	1874	1874	1880
Least monthly precipitation,	0·61	1·04	1·14
Date,	1881	1888	1892
Greatest amount in 24 hours,	1·67	2·56	1·81
Date,	3d, 1876	28th and 29th, 1887	6th, 1886
Greatest amount snowfall in 24 hours,	1·00	4·50	7·00
Date,	4th, 1886	6th, 1889	15th, 1893
Average number clear days,	9	8	8
Partly cloudy,	11	12	12
Cloudy,	10	10	10
Prevailing direction of wind,	NW	NW	W
Highest velocity, miles per hour,	50	36	60
Date,	3d, 1879	7th, 1893	1875

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for February, 1894.

County.	Station.	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers.
Allegheny,	Pittsburgh,	820	32·0	64	9	6	24	39·6	24·1	15·5	33	2·93	20·5	. . .	12	7	10	11	NW	O. D Stewart, W. B.
Berks,	Hamburg,	380	28·3	53	19	— 3	17	35·6	21·0	14·6	37	4·47	29·5	12·0	8	3	16	9	E	William Shipe.
Berks,	Reading,[2]	280	28·0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	5·59	. . .	. . .	14	. .	. .	. .	. . .	Franklin Yager.
Blair,	Altoona,	1,181	36·3	58	20	10	25	45·5	27·1	18·4	24	1·82	. . .	. . .	10	. .	. .	. .	. . .	Dr. C. B. Dudley.
Blair,	Blue Knob,	2,500	24·9	45	19, 28	— 6	24	30·2	19·6	10·6	21	4·97	38·5	18·0	15	3	13	12	NW	A. H. Boyle.
Blair,	Hollidaysburg,	947	27·2	57	19	— 9	17	38·5	15·9	22·6	51	4·23	26·0	5·0	13	13	5	10	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	20·8	45	19	—16	25	27·8	13·7	14·1	36	3·04	24·7	8·0	13	10	8	10	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy[1] (27 days),	304	30·4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3·77	. .	. .	10	7	14	6	N	J. C. Hilsman.
Bucks,	Quakertown,	536	26·9	51	18	— 7	17	36·0	17·8	18·2	47	4·16	16·5	10·0	9	4	15	9	NW	J. L. Heacock.
Cambria,	Johnstown,	1,184	29·8	34	28	1	17	38·4	21·1	17·3	48	3·32	23·0	1·0	20	4	10	14	NW	E. C. Lorentz.
Cameron,	Emporium,	1,050	25·6	53	28	— 9	17	35·7	15·5	20·2	50	3·08	18·3	. . .	8	5	17	6	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	26·0	53	18	— 8	17	35·2	16·7	18·5	42	4·11	20·5	4·0	11	13	5	10	N	F. C. Wintermute
Centre,	State College— Agricultural Experiment Sta.,	1,191	26·4	51	19	— 1	25	35·2	17·6	17·6	36	3·39	29·0	1·0	9	4	11	13	W	Prof. Wm. Frear.
Chester,	West Chester,	455	29·9	53	10, 18	9	25	37·2	22·6	14·6	28	4·66	18·0	3·0	13	12	2	14	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	30·6	59	10	2	25	40·4	20·8	19·6	36	4·60	22·9	6·0	12	11	6	11	W	W. T. Gordon.
Chester	Kennett Square,	275	30·7	57	18	3	25	40·2	21·2	19·0	43	5·08	19·0	3·0	12	6	6	16	NW	B. P. Kirk.
Chester,	Phœnixville,	190	30·0	56	18	4	25	38·0	22·1	15·9	33	3·99	23·5	6·0	14	7	4	17	NW	Knowles Croskey.
Chester,	Westtown (27 days),	350	29·1	52	10, 18	2	25	36·4	21·8	14·6	31	3·59	12·2	3·0	9	5	11	11	W	Harry Alger.
Clearfield,	Grampian,	1,450	23·8	50	28	— 6	24, 25	31·8	15·8	16·0	40	2·14	22·0	6·0	7	3	18	7	W	Nathan Moore.
Clinton,	Lock Haven,	560	27·8	55	8, 19	— 6	17	39·0	16·6	22·4	46	3·67	34·0	1·0	8	10	6	12	W	Prof. J. A. Robb.
Columbia,	Bloomsburg,— State Normal School,	500	26·2	48	18, 19	— 2	17	34·1	18·4	15·7	39	2·22	15·7	3·0	8	10	6	14	NW	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,	1,200	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	Prf. J. H. Montgomery.
Crawford,	Saegerstown,	1,200	23·6	50	9, 10	—14	5	31·9	12·2	22·7	43	2·70	12·5	. . .	7	6	8	14	NW	J. G. Apple.
Cumberland,	Carlisle,	480	28·9	56	18	— 2	17	37·0	20·8	16·2	42	4·53	32·0	8·0	11	12	4	12	W	J. E. Pague.
Cumberland,	Carlisle— Dickinson College,	480	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	Prof. C. F. Himes.
Dauphin,	Harrisburg,	361	29·0	51	18	3	25	34·7	22·5	12·2	26	4·56	23·5	. . .	13	6	8	14	E	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	190	32·2	55	10	5	25	39·1	25·3	13·8	30	3·17	16·2	6·0	11	3	16	9	N	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	1,400	21·6	40	8	2	24	. . .	. . .	. . .	. . .	.	18·0	2·0	. . .	16	6	6	E	C. F. Sweet.
Erie,	Erie,	681	25·0	50	9	— 2	25	32·0	19·0	13·0	32	3·55	. . .	.	14	7	6	15	S	P Wood, W. B.
Fayette,	Uniontown,	1,000	33·6	62	9	9	24	41·1	26·0	15·1	40	3·35	15·0	. . .	11	8	13	7	NW	Wm. Hunt.
Franklin,	Chambersburg,	618	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	David Rhea.
Fulton,	McConnellsburg,	875	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	T. F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	29·0	57	19	— 6	17	39·2	18·8	20·4	49	3·44	25·3	3·0	8	11	6	11	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	Prof. S. C. Schmucker.
Juniata,	Kilmer,*[1]	475	31·8	54	10	2	17	. . .	. . .	. . .	. . .	4·57	37·3	8·0	9	10	8	10	W	R. J. Mickey.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	29·9	53	10	1	17	38·0	21·8	16·2	41	3·50	22·8	7·0	7	12	5	11	E	W. E. Bushong.
Lawrence,	New Castle,	932	27·4	54	9, 28	— 3	2	36·8	17·9	18·9	35	1·76	11·0	. .	9	9	2	17	W	Wm. T. Butz.
Lebanon,	Lebanon,	458	28·4	53	18	— 1	17	36·8	19·9	16·9	40	4·23	25·2	4·0	12	9	6	13	NW	G. W. Hayes, C.E.
Lehigh,	Coopersburg,	520	28·6	54	8	1	25	37·1	20·0	17·1	38	4·20	17·7	9·0	11	11	9	8	NW	Dr. M. H. Boye.
Luzerne,	Drifton (23 days),	1,683	27·8	54	8	—10	26	44·8	10·9	33·9	50	3·40	34·0	11·0	11	6	8	9	N	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	28·4	56	19	— 1	17, 25	38·8	18·1	20·7	40	4·50	25·0	. . .	9	14	3	11	NW	A. W. Betterly.
McKean,	Kane,	2,000	23·0	48	28	— 8	24	32·0	14·0	18·0	36	2·30	14·7	6·0	7	8	8	12	SE	C. H. Kemp.
McKean,	Smethport,	1,500	22·8	51	28	—15	25	32·3	13·2	19·1	52	3·35	15·5	. . .	9	. .	. .	. .	NW	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	25·7	57	9	— 2	25	35·0	16·4	18·6	34	1·[illegible]	10·5	. . .	7	9	5	14	NW	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	29·9	54	18	3	17, 25	37·0	22·8	14·2	36	4·25	19·5	3·0	11	12	5	11	NE	Charles Moore, D.D.S.
Montgomery,	Skippack,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	B. W. Dambly.
Northampton,	Easton— Lafayette College,	325	26·6	51	8	— 2	17	34·8	18·4	16·4	36	3·39	18·6	. . .	9	10	6	12	. . .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	30·6	56	18	0	17	38·8	22·5	16·3	43	4·69	27·4	7·5	15	10	9	9	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	32·0	56	8	4	25	38·5	25·3	13·2	26	3·07	11·5	. . .	12	5	11	12	NE	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	32·4	57	18	3	25	39·5	25·4	14·1	24	4·33	12·9	3·0	13	7	9	12	NE	John Comly.
Philadelphia,	3011 Locust Street,	100	31·6	55	18	4	25	38·2	25·1	13·1	24	4·74	12·3	2·0	14	9	8	11	NE	R. L. Paddock.
Pike,	Blooming Grove,*[1]	. . .	23·4	47	18	—16	25	. . .	. . .	. . .	. . .	3·40	34·0	10·0	6	6	10	12	W	John Grathwohl.
Potter,	Shingle House,	1,475	21·6	51	28	—18	25	32·5	10·8	21·7	51	3·02	21·0	6·0	11	6	8	14	W	C. D. Voorhees, M.D.
Schuylkill,	Girardville,[1]	1,000	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. . .	E. C. Wagner.
Snyder,	Selins Grove,	455	29·0	52	18	— 6	17	38·1	20·0	18·1	40	3·87	28·5	10·0	9	. .	22	6	NW	J. M. Boyer,
Somerset,	Somerset,	2,250	26·2	56	9	0	24, 25	34·0	18·5	15·5	41	5·20	40·2	3·0	11	1	13	14	NW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	23·4	56	19	—16	25	. . .	. . .	. . .	. . .	2·25	19·0	10·5	8	9	8	11	S	H. D. Deming
Union,	Lewisburg,	450	26·2	51	19	—16	17	36·4	16·0	20·4	52	2·46	22·5	4·0	8	13	8	7	W	Prof. W. G. Owens.
Wayne,	Dyberry,	1,100	20·2	49	18, 19	—24	25	31·8	8·5	23·3	49	2·73	30·0	20·0	11	6	12	10	NW	Theodore Day.
Wayne,	Honesdale,	1,000	22·8	49	18	—20	25	34·0	11·5	22·5	48	3·63	32·0	24·0	11	11	9	8	. . .	John Torrey.
Wayne,	(Salem Corners) Hamlinton,	1,600	22·5	57	19	—10	25	30·2	14·8	15·4	34	4·90	42·3	30·0	13	6	9	13	W	T.B. Orchard, M D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	29·4	60	10	5	5	36·5	22·2	14·3	31	2·31	19·0	. . .	8	. .	. .	. .	. . .	Murray Forbes.
Westmoreland,	Ligonier,	1,750	29·5	58	10	— 4	17	40·2	18·8	21·4	56	2·78	26·0	1·0	11	11	7	10	. . .	C. D. Ambrose.
Wyoming,	South Eaton,	660	24·8	58	27	— 9	17, 25	34·4	15·1	19·3	54	2·79	16·0	3·0	10	8	9	11	NW	B. M. Hall.
York,	York,	385	29·6	54	10	— 2	17	38·2	21·0	17·2	44	4·20	25·2	5·0	11	9	11	8	NW	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. *Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.